British Journal of Anæsthesia

Vol. XXV, No. 3 JULY 1953

EDITORIAL

"I would have everie man write what he knowes, and no more."

As no one, not even an editor, can be equally *au fait* with all branches of his subject, he must at times fail to distinguish the specious from the genuine article. He will consequently echo the wish so definitely expressed by Montaigne nearly four hundred years ago. Montaigne apparently had had experience of two sorts of people. One kind was exemplified by his servant whom he described as a "simple, rough hewen fellow, a condition fit to yeeld a true testimonie." The other kind were "subtile people who though they may observe things more exactly yet amplifie and glose them." "These never represent things truly but fashion and maske them according to the visage they saw them in . . . and to draw you on to beleeve them they commonly adorn, enlarge, yea and hyperbolize the matter." For example if some of these people have seen Palestine they presume "to tell us newes of all the world besides". It is these people who stir Montaigne to say "I would have everie man write what he knowes and no more, not only in that but in all other subjects. For one may have particular knowledge of the nature of one river, and experience of the qualitie of one fountaine, that in other things knowes no more than another man, who nevertheless

to publish this little scantling will undertake to write of all the physickes. From which vice proceed divers great inconveniences." To-day, one of the most conspicuous of these inconveniences is the enormous amount of reading matter published; so we do our best for our public by attending to the quality rather than the quantity of the articles we publish.

We celebrate this year the centenary of the hypodermic syringe. In 1853, Pravaz invented a syringe and trocar for the treatment of aortic aneurysm. The technical invention was considerable, but Pravaz's vision was narrow. In the same year, Alexander Wood, M.D., F.R.C.P.E., F.R.S.E. (see frontispiece), was contemplating the administration of narcotics by the parenteral route. Taking the bee's sting as his model, he constructed the first hypodermic needle and made a syringe which, however, was not satisfactory. Obtaining one of Pravaz's syringes, Wood adapted this to his use, and so the hypodermic technique was evolved. From the outset, Wood envisaged the effect of this method upon the whole frame of medicine, and there can be little doubt that few inventions have so changed the face of our profession.

At this moment the number of drugs and of techniques at our disposal is rapidly increasing, but the frontiers are being pushed forward too often without broad vision and careful logic. The time has come to consolidate our gains, to consider the value of the means at our disposal and the effects which it is useful to produce. For this we need to develop that broadness of vision which so distinguished Alexander Wood, and let us hope that our educational facilities are being so employed that we can, with the foresight of Milton, say,

" Tomorrow to fresh Woods and Pasteurs new."

The Editors and Board of Management of the Journal are extremely grateful to Dr. Martin Clover for giving his permission to reproduce the picture of Joseph Thomas Clover on the cover of this Journal, and on future July issues. This drawing was made by Miss Barbara Duckworth from the original painting loaned to the Royal College of Surgeons by Dr. Martin Clover, and painted when Joseph Clover was a young man, by his uncle, another Joseph Clover.

We are grateful also to the President and Authorities of the Royal College of Surgeons for providing the facilities for the portrait to be copied.

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AN EXAMINATION OF OXYGEN AND CARBON DIOXIDE CONCENTRATIONS IN ADULT OXYGEN TENTS

By R. E. JAHN

THIS work was undertaken in order to establish, if possible, quantitative relationships between the rate of flow of oxygen into an adult oxygen tent, the rate of leakage from the tent, and the rate of evolution of carbon dioxide by the patient. It was hoped that it would be possible to predict a "maintenance rate" for a normal tent, a given rate of flow of oxygen being correlated with the resultant concentrations of oxygen and carbon dioxide. It will be shown that it is not possible to achieve such a correlation, although it is possible to predict the maximum concentration of carbon dioxide from the corresponding oxygen concentration and flow rate.

GENERAL THEORETICAL CONSIDERATIONS

(*a*) *Oxygen Concentraton*

Oxygen tents are used to supply patients with an atmosphere having a higher concentration of oxygen than that present in ordinary air. This concentration will be specified by the physician, and it is therefore important to study the factors which affect the concentration of oxygen inside an oxygen tent.

Suppose an oxygen tent, with the patient inside it, requires an oxygen flow rate of 6 to 8 litres per minute to keep the concentration at 50 per cent. Why is this flow required? The patient will be using some of the oxygen to satisfy his metabolic needs but this will never account

for more than about 0.5 litre per minute, leaving an excess in this case of 5.5 to 7.5 litres per minute. This can only be required to replace oxygen lost from the tent. The canopy is made from an almost impermeable material so that the leakage must occur at the junction of the canopy and the bed clothes, and to a much smaller extent at the junction of the canopy with the ice cabinet or control unit.

The loss of oxygen from the tent is caused by two processes which take place simultaneously while the tent is in use. The first process is the obvious one of displacement of the tent atmosphere by incoming oxygen. The second is one of diffusion which takes place whether oxygen enters the tent or not. It is caused by air movements at the site of any leaks, and by the kinetic energy of the gas molecules, which will cause gas exchange between the tent atmosphere and the air outside even in the absence of air movement. The quantity of air which enters and leaves the tent by this process may be designated the " diffusion exchange ".

Diffusion exchange is quite unaffected by the oxygen concentration inside the tent. A tent filled with say 80 per cent oxygen will allow the oxygen concentration to fall to 70 per cent more quickly than from 40 per cent to 30 per cent because each litre of gas which leaves the tent is replaced by 1 litre of air. The effect of replacing 1 litre of 80 per cent oxygen by 1 litre of air (21 per cent oxygen) is more marked than in the case of a similar replacement involving 40 per cent oxygen. It might be possible to arrange for radioactive oxygen atoms to be put into a tent as " tracers " without altering the oxygen concentration. It would be found that even if the oxygen concentration were 21 per cent inside the tent, the same as in the air outside, there would still be a steady loss of radioactive oxygen atoms from the tent.

The effect of these two processes of displacement and diffusion is that in a tent maintained at 50 per cent oxygen, each litre which leaves the tent contains 0.5 litre of oxygen, whereas each litre which enters the tent contains only 0.21 litre of oxygen. It is this loss which necessitates continuous topping up with oxygen. It is possible to derive a formula giving the relationship between these various factors.

Let x = concentration of oxygen in the tent, expressed as a percentage.
M = maintenance flow rate in litres per minute for a concentration x inside the tent.
E = diffusion exchange rate in litres per minute.

Since the maintenance rate M is that rate which produces neither an increase nor a decrease in the oxygen concentration x, and hence in the volume of oxygen in the tent, the following statements may be made. During each minute M litres of oxygen pass into the tent in the form of maintenance rate oxygen, displacing M litres of tent atmosphere. This atmosphere contains x per cent oxygen so that the volume of oxygen displaced will be $\frac{Mx}{100}$ litres.

During the same period of one minute the diffusion exchange of E litres takes place so that $\frac{21E}{100}$ litres of oxygen enters the tent in the form of air diffusing inwards, and $\frac{xE}{100}$ litres of oxygen leaves the tent by diffusing outwards.

At the end of one minute the volume of oxygen in the tent is the same as it was at the beginning. This is implied in the definition of the maintenance rate. Equating the volumes of oxygen entering and leaving the tent:

$$M + \frac{21E}{100} = \frac{Mx}{100} + \frac{Ex}{100}$$

$$\text{therefore } E = \frac{M(100 - x)}{x - 21} \qquad \text{.....(i)}$$

Thus if the maintenance rate, M, were 8 litres per minute and the oxygen concentration x, were maintained at 50 per cent, then E, the diffusion exchange rate, amounts to the surprisingly high figure of 13.8 litres per minute. In

other words, in this particular case, 13.8 litres of tent atmosphere leave the tent, and are replaced by 13.8 litres of air during every minute. The diffusion exchange rate E, can be estimated following oxygen analyses of the contents of the tent. Since the diffusion exchange depends critically upon the manner in which the canopy is tucked under the bedding it is altered whenever the tent is taken down and put up, even if this is done using the same bed and bedding.

Another factor affects the diffusion exchange and maintenance rate. This may be described as the "bellows" effect. A restless patient will cause movements of the bed springs which will alternately increase and decrease the volume of the tent. This will have a marked effect on the diffusion exchange rate, but cannot unfortunately be allowed for separately in these calculations.

(b) Carbon Dioxide Concentration

If the oxygen tent were completely sealed the only input of oxygen required would be 0.5 litre per minute to replace that used by the patient's metabolism. Although this would be economical in oxygen it would allow a rapid accumulation of carbon dioxide to take place. A tent can be operated under these conditions but carbon dioxide must then be absorbed by chemical means such as using soda lime. It is doubtful whether the economy in oxygen justifies the cost of the soda lime, and the increased attention which must be given to the tent, both in the form of carbon dioxide analyses to determine the state of exhaustion of the soda lime, and in ensuring that the canopy is completely sealed.

In this country it is almost universal practice to operate adult oxygen tents on a much higher oxygen flow rate than that needed to supply the patient's metabolic needs. In this way the carbon dioxide passes out with the atmosphere leaking from the tent. The maximum concentration of

carbon dioxide which can accumulate under any given set of conditions may be estimated as follows:

If the concentration of carbon dioxide in the tent is C per cent and the total displacement from the tent is D litres per minute, then in one minute the loss of carbon dioxide from the tent will be C per cent of D litres or $\frac{CD}{100}$ litres per minute. If this volume is less than that of the carbon dioxide evolved by the patient (say, L litres per minute), then the concentration will rise and conversely. Ultimately an equilibrium condition will arise in which:

$$\frac{CD}{100} = L$$

or $$C = \frac{100\,L}{D}$$

The quantity D is the sum of the maintenance rate M and the diffusion exchange rate E used in the earlier calculation. From that calculation,

$$E = \frac{M(100 - x)}{x - 21}$$

and if this is substituted in the equation

$$D = M + E$$

then $$D = M + \frac{M(100 - x)}{x - 21}$$

or $$D = \frac{79\,M}{x - 21}$$

Then on substituting this value of D into the equation

$C = \frac{100L}{D}$ the value for C becomes:

$$C = \frac{100\,L\,(x - 21)}{79\,M} \qquad \text{.....(ii)}$$

This formula gives the value of the maximum concentration of carbon dioxide in terms of the maintenance rate of oxygen M, the patient's rate of carbon dioxide evolution L, and the equilibrium oxygen concentration x.

Thus if a patient evolves 200 ml. of carbon dioxide per minute, and the tent can be maintained at 50 per cent oxygen with a maintenance flow rate of 8 litres per minute, the carbon dioxide concentration may eventually rise to 0.9 per cent.

(*c*) *Flushing Volume*

So far attention has been directed to a tent in which a high oxygen concentration has already been produced. Consideration will now be given to the situation arising when the tent has just been erected and contains atmospheric air. A certain volume of oxygen must be put into the tent merely to replace the air by, say, 50 per cent oxygen. This process can be conveniently called "flushing" the tent, and the requisite volume of oxygen the "flushing volume". Suppose an ideal state is assumed, that there is no leakage of air into the tent whilst flushing is going on. The volume of oxygen required to raise the concentration in the tent from 21 per cent (air) to x per cent can be calculated as follows:

Let V = volume of tent in litres.
y = total volume of oxygen passed into the tent, in litres.
x = resultant oxygen concentration.

When a small volume δy of oxygen is added to the tent, the same volume, δy, of x per cent oxygen, will be displaced from it, The concentration of oxygen in the tent will increase from x to $x + \delta x$, and the volume of oxygen in the tent will increase to $(x + \delta x)$ per cent of V litres or $\frac{(x+\delta x)}{100} V$ litres. The original volume of the oxygen in the tent was x per cent of V litres. This has been increased by δy, the quantity of oxygen added, and decreased by x per cent of δy, the amount of oxygen displaced by adding δy of oxygen.

$$\text{therefore } \frac{(x+\delta x)V}{100} = \frac{x}{100} V + \delta y - \frac{x}{100} \delta y$$

$$\text{or } \delta y = \frac{V.\delta x}{100 - x}$$

The volume of oxygen required to raise the oxygen concentration from x_1 per cent to x_2 per cent will be y litres where

$$y = \int_0^y dy = \int_{x_1}^{x_2} \frac{V}{100 - x} \, .dx$$

$$= -V \left[\log_e (100 - x) \right]_{x_1}^{x_2}$$

$$= -V \left[\log_e (100 - x_2) \right] + V[\log_e (100 - x_1)]$$

By putting the positive term first and converting to logarithms to the base 10 we have

$$y = 2.3026 \, V \, [\log_{10} (100 - x_1) - \log_{10} (100 - x_2)] \ldots\ldots\ldots\ldots \text{(iii)}$$

The volume of a normal adult tent is about 500 litres. From the relation above the quantity of oxygen required to raise its concentration from 21 per cent to 50 per cent is 229 litres. This would correspond to a " flush " flow-rate of 12 litres per minute running for 19 minutes.

The above calculations take no account of the diffusion exchange. In actual fact air will enter the tent even while it is being flushed. This is not allowed for in the calculation, which is thus a minimum figure. It shows, for example, that on a flow rate below 6 litres per minute, neglect to allow for the quantity of oxygen needed for flushing may result in the tent never containing 50 per cent oxygen, because it has not been flowing in for long enough before the tent is opened again to attend to the patient.

EXPERIMENTAL VERIFICATION OF CALCULATIONS

The theoretical considerations just given can be checked against (*a*) statements made in the literature dealing with oxygen therapy, and (*b*) experiments using a tent.

(*a*) STATEMENTS IN THE LITERATURE

Campbell and Poulton (1938) describe an oxygen tent which uses a maintenance flow rate of 1 to 3 litres per

minute of oxygen. Carbon dioxide absorption is employed and it is stated that careful attention must be paid to the apparatus, and hourly analyses of the tent atmosphere must be made. Andrews (1943) gives detailed instructions for operating various types of commercial tents and emphasises the need for frequent oxygen analyses. He suggests that the concentration of oxygen can be raised to 50 per cent with a 15 minute flow of 15 litres per minute. This amounts to 225 litres of oxygen, and agrees with the minimum figure of 229 litres per minute derived from formula (iii) above. He recommends a high maintenance flow rate of 10–14 litres per minute if oxygen analyses are not going to be taken and it is desired to run the tent at 50 per cent oxygen. If oxygen analyses are taken the figure may be reduced but he states that flow rates below 6 litres per minute should never be used because the carbon dioxide concentration may well rise to over 2 per cent. These statements support the theoretical views so far expressed here.

Barach (1947) describes a closed head tent which is small in volume and has very little leakage. By using an injector on the oxygen line and drawing air in with the oxygen, a low flow rate of oxygen is combined with a high rate of air/oxygen flow through the tent, and carbon dioxide is effectively removed. Barach estimates the oxygen flow rates which are required to keep the carbon dioxide concentration below 1 per cent for various rates of carbon dioxide evolution by the patient. He predicts that for a patient evolving 308 ml. of carbon dioxide per minute, the required oxygen flow rate is 11.5 litres per minute, to keep the oxygen concentration at 50 per cent and the carbon dioxide concentration below 1 per cent.

The calculations used here are based on similar principles to those used by Barach. This is justifiable although Barach blows in air with the oxygen whereas we allow air to enter

at a later stage, because the dilution effect is the same, and the equilibrium state will be the same no matter how the diluting air enters the tent. If formula (ii) above is used to check Barach's figures, the oxygen flow rate required amounts to 11.3 litres per minute which is a very fair agreement.

The use of an injector as described by Barach does not save oxygen, but is a very convenient method of controlling the oxygen concentration in small rigid tents where the diffusion exchange rate is low. It should be applicable to the tents and boxes used for babies.

(b) EXPERIMENTS USING A TENT

One factor which greatly facilitated this work was that an oxygen analyser especially designed for use with oxygen tents was available. This analyser employs the Pauling principle and depends upon the paramagnetic properties of oxygen. It enables analyses of the oxygen concentration in an oxygen tent to be made at intervals of about one minute and is therefore particularly suitable for the purpose envisaged.

Carbon dioxide analyses were made using a slightly modified R. R. H. carbon dioxide indicator (Ringrose et al., 1950) which gives a continuous visual indication of the carbon dioxide concentration. The readings were checked against analyses using a standard Orsat apparatus.

The object of the work reported here was to establish a satisfactory technique for operating oxygen tents. Two aspects of the operation of a tent are not dealt with in detail here. These are the temperature and humidity. The tents examined were found to be satisfactory in both these respects. There is no doubt that the ice cabinet and the air circulation arrangements normally make the tent very comfortable for the patient.

Experimental Check of Flushing Volume Calculation. Two types of commercially available oxygen tents were used in these experiments. They both employed ice cooling, but tent A had an electric motor blower which could be switched on to increase the circulation, whereas tent B did not. At the beginning of each test the tent was set up and the volume of oxygen required to reach 50 per cent oxygen was found experimentally and compared with the calculated volume. The results are given in tables I and II.

TABLE I

Tent A. Results of experiments on flushing rates

Oxygen flow rate, litres per min.	Time taken to reach 50% oxygen, min.	Oxygen required litres		Ratio a/b	Volunteer in tent, yes or no
		Measured (*a*)	Predicted using formula (iii) (*b*)		
13.5	27	364	282	1.3	No
13.5	32	432	282	1.5	Yes
25.0	12.5	313	282	1.1	No
50.0	4.5	225	282	0.8	No
100.0	2.5	250	282	0.9	No

The results are the means of several determinations. An additional, temporary, oxygen inlet was arranged for the high oxygen flow rates. The volume of tent A was about 600 litres. This volume was chosen as representing the maximum likely to be found in practice. The exact volume of a tent will depend upon how the tent is assembled and can vary between 300 and 600 litres. The volume of tent B was about 540 litres.

It is interesting to observe with both tents that the longer the time taken to flush the tent the greater the discrepancy

TABLE II

Tent B. Results of experiments on flushing rates

Oxygen flow rate, litres per min.	Time taken to reach 50% oxygen, min.	Volume of oxygen required, litres		Ratio a/b	Volunteer in tent, yes or no
		Measured (*a*)	Predicted using formula (iii) (*b*)		
11.5	25	288	269	1.1	No
11.5	29	334	269	1.2	Yes

between the measured volume of oxygen used, and that predicted from formula (iii).

This is to be expected from the effect of the diffusion exchange taking place while the tent is being flushed. In table II the bellows effect is quite clearly shown in the increased time taken to flush the tent and the consequent loss of oxygen when a volunteer was inside.

Experiments on Maintenance Rates

To obtain the maintenance oxygen flow rate the tent was first flushed to the desired concentration and the oxygen input was adjusted by trial so that the concentration neither rose nor fell over a period of 30 minutes. In one experiment it was found that an oxygen flow rate of 5 litres per minute maintained a concentration of 50 per cent. From formula (i) it was calculated that E, the diffusion exchange rate, was 8.6 litres per minute. From this figure it was then deduced that to maintain an oxygen concentration of 70 per cent, 14.1 litres per minute of oxygen would be required, and to maintain 80 per cent oxygen, 25.4 litres per minute of oxygen would be required. These particular figures were not checked experimentally but are quoted as an example of the applicability of formula (i).

In another experiment where great care was taken to seal the canopy to the bed-clothes, it was found that a maintenance flow as low as 2 litres per minute maintained an oxygen concentration of 50 per cent. However, in this case the carbon dioxide concentration rose rapidly to above 2 per cent.

In further experiments it was found that the presence or absence of a volunteer in the tent had little effect on maintenance rates so long as he remained still. It was impossible, however, to operate a tent at a given oxygen concentration accurately without frequent analyses of the atmosphere of the tent being necessary. This was in spite of the fact that the same bed and bedding were used throughout and one tent was used for many experiments.

Experimental Check on Calculation of Carbon Dioxide Accumulation

The formula derived earlier (ii) takes into account the factors causing diffusion and would be expected to be quite accurate. It was tested by setting up a tent without a volunteer, and admitting metered quantities of oxygen and carbon dioxide. By taking frequent analyses it was possible to adjust the oxygen concentration to 50 per cent and determine when the carbon dioxide concentration was also at equilibrium. Equilibrium was considered to be reached when the tent atmosphere was unaltered after 30 minutes.

The results of these experiments are given in table III.

The experimental figures may be said to be in reasonable agreement with those deduced theoretically. Thus in a typical case in which 7 litres per minute of oxygen are used and the patient evolves 200 ml. per minute of carbon dioxide, the carbon dioxide concentration would not be expected to exceed 1 per cent.

Further experiments were performed in which volunteers

TABLE III

Calculated and Experimental Carbon Dioxide Concentrations in Tent B

The oxygen concentration was held at 50% for various oxygen flow rates by suitably arranging the leaks

Maintenance oxygen flow rate, litres per min.	Rate of Input of carbon dioxide, ml. per min.	Equilibrium Carbon Dioxide Concentration %	
		Predicted from formula (ii)	Experimental
3	200	2.45	2.90
	400	4.9	5.0
5	200	1.47	—
	400	2.94	—
6	200	1.23	—
	400	2.45	2.50
7	200	1.05	—
	400	2.10	—
10	200	0.74	0.80
	400	1.47	1.50
12	200	0.62	—
	400	1.23	—

lay in the tent. They were healthy male adults whose weights ranged from 10 st. 10 lb. (68.5 kg.) to 15 st. 0 lb. (96 kg.). One experiment was discontinued when it was found that an oxygen maintenance flow rate of 3 litres per minute maintained an oxygen concentration of 50 per cent but allowed the carbon dioxide concentration to reach 2.7 per cent in 50 minutes.

These experiments support our own calculations and also the statement made by Andrews (1943) that oxygen flow rates should never be less than 6 litres per minute. They also lend support to the current American practice of operating tents with an oxygen flow rate of 10 to 14 litres per minute.

SUGGESTED METHOD OF OPERATION OF AN ADULT OXYGEN TENT, GIVING CONTROL OF BOTH OXYGEN AND CARBON DIOXIDE

It is doubtful whether the current practice of predicting the oxygen concentration from the flow rate can be considered reliable. The only reliable method of knowing the concentration of oxygen inside an oxygen tent is to undertake periodic oxygen analyses. There does not seem to be any way of avoiding this. The most straightforward method of ensuring that carbon dioxide accumulation is not occurring is to undertake periodic carbon dioxide analyses as well. These carbon dioxide analyses can be avoided by utilising the formulæ derived in this report. The method of doing so is given below.

The tent is assembled according to the maker's instructions. The oxygen flow rate is then adjusted to the highest available on the flowmeter. About 300 litres of oxygen are passed into the tent as quickly as possible if 50 per cent oxygen is required, and the tent atmosphere is analysed to check that the oxygen concentration has been reached. If not, more oxygen must be added. An approximate estimate is now made of the rate of carbon dioxide evolution by the patient, and the maximum allowable carbon dioxide concentration inside the tent is decided upon. The required oxygen maintenance flow rate is calculated from a modified form of formula (ii):

$$M = \frac{100\,L\,(x-21)}{79\,C}$$

where M = maintenance flow rate of oxygen in litres per minute
L = rate of carbon dioxide evolution by the patient in litres per minute
x = oxygen concentration (per cent)
C = maximum allowable carbon dioxide concentration (per cent).

The amount of leakage is arranged by trial following oxygen analyses at intervals, to give the oxygen concentration required. Normally these leakages, where necessary, may conveniently be arranged by controlled opening of the sleeves. In the accompanying table a few maintenance flow rates are given as examples.

TABLE IV

Maintenance oxygen flow rates required for given oxygen and carbon dioxide concentrations in adult oxygen tents

Carbon dioxide evolution by patient, litres per min.	Maximum carbon dioxide concentration in tent, %	Maintenance flow rate of oxygen in litres per min. required to maintain carbon dioxide at level of 2nd col. and also	
		40% oxygen	50% oxygen
0.2	0.5	9.6	14.7
	1.0	4.8	7.4
0.3	1.0	7.2	11.0
	2.0	3.6	5.5

The figures in the table make due allowance for leakage of air into the tent and of tent atmosphere from it. An oxygen tent operated in the manner suggested could be used for control experiments if it should be desired to examine critically the value of oxygen in a given treatment.

SUMMARY

It is shown that to ensure a pre-determined oxygen concentration in an oxygen tent, it is necessary to carry out periodical oxygen analyses of the tent atmosphere. Although the leakage taking place cannot be predicted it is possible to carry out calculations on: (*a*) the volume of oxygen required to bring the tent concentration to a certain figure; (*b*) the amount of diffusion taking place from the tent; and

(*c*) the quantity of carbon dioxide which may be expected in the tent. Where appropriate these calculations have been verified experimentally, drawing upon results obtained experimentally and upon those reported in the literature.

A method of operation of a tent is outlined by which it could be made to contain accurately known concentrations of oxygen and carbon dioxide.

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ARRHYTHMIA DURING KEMITHAL ANÆSTHESIA

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A SURVEY of the literature relating to thialbarbitone (Kemithal) anæsthesia would indicate that its effect on the cardiovascular system resembles that of thiopentone.

Carrington and Raventos (1946), investigating the pharmacology of thialbarbitone, state that the fall of blood pressure that it causes corresponds to that found during thiopentone anæsthesia and they mention no cardiac irregularities. Mackintosh and Scott (1946), in a series of 400 patients between the ages of 10 and 80 years, undergoing a variety of operations under thialbarbitone anæsthesia, found, on electrocardiographic examination, no alterations of significance. Gordon and Gibbon (1946), in a series of 372 cases, observed a slight fall in systolic and diastolic blood pressures and in the pulse pressure. They noticed one case of bradycardia and three cases of tachycardia, the latter being, in their opinion, due to surgical factors, but no irregularities. Halton (1946), using thialbarbitone for thoracic operations mentions no cardiovascular disturbances. Johnstone (1951), writing on pulse irregularities occurring during thiopentone anæsthesia, found evidence that carbon dioxide accumulation caused ventricular tachycardia, bigeminal rhythm, ventricular extrasystoles and sinus tachycardia in a series of 25 cases on which electrocardiographic records were taken. In 100 cases in which carbon dioxide was not allowed to accumulate, only one patient showed an arrhythmia which consisted of alternat-

ing ventricular extrasystoles for a few seconds after induction. He states that a similar series of cases receiving thialbarbitone showed that " the influence of this drug on the heart and autonomic system does not differ appreciatively from that of thiopentone ".

I have received the impression, clinically, that the incidence of arrhythmia is greater when using thialbarbitone (Kemithal) than when using thiopentone and the study of records of 2,260 anæsthetics, of which 1,437 were with thiopentone and 823 thialbarbitone confirms this impression. The object of this paper is to compare the incidence of *sustained* arrhythmia during the *first twenty minutes* of anæsthesia with each of these drugs.

MATERIAL

The anæsthetic requirements of different groups of patients made certain variations of technique essential, and thus the cases have been divided into four groups according to the anæsthetic technique used; each group is further

TABLE I
Age Groups

Type of anæsthetic	15–29 years	30–49 years	50–69 years
Group Ia	93 (16.1%)	271 (48.7%)	210 (35.2%)
Ib	15 (11.1%)	48 (35.5%)	72 (53.3%)
Group IIa	22 (8.6%)	112 (43.5%)	123 (47.8%)
IIb	28 (14.4%)	66 (34%)	100 (51.5%)
Group IIIa	17 (13.4%)	61 (48.4%)	48 (38.1%)
IIIb	16 (13.9%)	51 (44.4%)	48 (41.7%)
Group IVa	22 (7.4%)	138 (46.4%)	137 (46.1%)
IVb	9 (4.9%)	78 (43.1%)	94 (51.9%)
Group Va	7 (10.3%)	27 (39.6%)	34 (50%)
Vb	8 (9.8%)	43 (53.1%)	30 (37%)
Group VIa	27 (23%)	59 (51.3%)	29 (25.2%)
VIb	38 (32.5%)	58 (49.6%)	21 (18%)
Total	302 (13.4%)	1,012 (44.8%)	946 (41.5%)

TABLE II
Types of Operation

Group	Head and neck	Abdominals	Urological and Gynæcological	Hernia	Miscellaneous	Breasts	Non-toxic thyroid-ectomies	Toxic thyroid-ectomies
Ia	—	405 (70.6%)	43 (6.5%)	113 (19.5%)	13 (3.4%)	—	—	—
Ib	—	91 (68.1%)	13 (9.8%)	25 (17.5%)	6 (4.5%)	—	—	—
IIa	39 (17.2%)	140 (53.6%)	43 (12.8%)	11 (3.6%)	7 (7.4%)	17 (5.2%)	—	—
IIb	71 (38.5%)	55 (26%)	28 (19.5%)	9 (4.6%)	8 (4.6%)	23 (11.9%)	—	—
IIIa	—	88 (70.7%)	17 (11.1%)	21 (16.6%)	—	—	—	—
IIIb	—	84 (76.1%)	12 (9.7%)	19 (14.1%)	—	—	—	—
IVa	8 (2.9%)	260 (87.5%)	24 (8%)	5 (1.1%)	—	—	—	—
IVb	13 (8.9%)	154 (89.3%)	10 (5.9%)	4 (2.2%)	—	—	—	—
Va	—	—	—	—	—	—	68 (100%)	—
Vb	—	—	—	—	—	—	77 (100%)	—
VIa	—	—	—	—	—	—	—	115 (100%)
VIb	—	—	—	—	—	—	—	117 (100%)

TABLE III
Sex Incidence

Group	Males	Females	Total
Ia	337 (58.7%)	237 (41.3%)	574
Ib	71 (52.6%)	64 (47.4%)	135
IIa	144 (56%)	113 (44%)	257
IIb	78 (40.2%)	116 (59.8%)	194
IIIa	82 (65.1%)	44 (34.9%)	126
IIIb	66 (57.3%)	49 (42.7%)	115
IVa	208 (70.1%)	89 (29.9%)	297
IVb	105 (57.9%)	76 (43.1%)	181
Va	9 (13.2%)	59 (86.8%)	68
Vb	4 (4.9%)	77 (95.1%)	81
VIa	15 (13%)	100 (87%)	115
VIb	6 (5.1%)	111 (94.9%)	117

sub-divided into the cases receiving thiopentone, (*a*), and those receiving thialbarbitone, (*b*). The patients in Group I were given a thiobarbiturate followed by d-tubocurarine chloride, gas and oxygen; in Group II, they had the same anæsthetic as those in Group I but were intubated after the d-tubocurarine had been given; in Group III the patients had the site of the incision infiltrated with 0.5 per cent procaine containing 1 : 100,000 adrenaline before the induction of anæsthesia which was the same as in Group I; Group IV also received a local infiltration but the anæsthesia was followed by intubation as in Group II. As patients undergoing thyroidectomy appeared to be particularly prone to develop arrhythmia during the induction of anæsthesia, non-toxic and thyrotoxic patients have been considered separately in Groups V and VI respectively. These patients undergoing thyroidectomy received the same anæsthetic as the patients in Group IV, with the exception of three cases in Group V and seven in Group VI where the adrenaline was omitted from the local anæsthetic solution. Tables I, II and III show the composition of the groups of cases anæs-

thetized with thiopentone and thialbarbitone respectively as regards age, surgical conditions and sex incidence. In regard to table II, while all series are not strictly comparable, the pulse observations were made before the surgical interference took place and therefore the type of operation can have little bearing.

METHOD

The pulse was palpated at the superficial temporal artery and the rate and the presence of arrhythmia was recorded at two and a half minute intervals during the induction of anæsthesia. Electrocardiographic recordings were taken in 52 cases, half of which had thiopentone and half thialbarbitone.

RESULTS

A case was considered to have shown a sustained arrhythmia due to the anæsthetic if the arrhythmia occurred within ten minutes of the induction of anæsthesia and lasted for at least ten minutes. It was felt that later in the anæsthesia other factors might come into play and that the more transient arrhythmia might be missed by an anæsthetist working alone. The consistent arrhythmia was detected by palpation on all occasions in which the E.C.G. record, made by the independent observer, showed it to be present; on no occasion in those cases observed by the E.C.G. was an arrhythmia detected by palpation which was not confirmed electrocardiographically. The sustained arrhythmias, apart from the time of onset and the duration, had two other characteristics, namely that they consisted of a completely irregular pulse associated with a bigeminal pulse and/or a bradycardia (as a rule all three types were present in each case) and on cessation they did not recur later during the anæsthesia.

Table IV shows the incidence of a sustained arrhythmia

TABLE IV
Incidence of Arrhythmia

Type of anæsthetic	Number of cases	Number showing arrhythmia	Percentage
Ia. Thiopentone, N_2O, O_2, d-tubocurarine	574	11	1.1
Ib. Thialbarbitone, N_2O, O_2, d-tubocurarine	135	16	11.8
IIa. Thiopentone, N_2O, O_2, d-tubocurarine, intubated	257	22	8.6
IIb. Thialbarbitone, N_2O, O_2, d-tubocurarine, intubated	194	41	21.1
IIIa. Local, thiopentone, N_2O, O_2, d-tubocurarine	126	3	2.4
IIIb. Local, thialbarbitone, N_2O, O_2, d-tubocurarine	115	18	15.6
IVa. Local, thiopentone, N_2O, O_2, d-tubocuraine, intubated	297	22	7.5
IVb. Local, thialbarbitone, N_2O, O_2, d-tubocurarine, intubated	181	25	13.8
Va. Non-toxic thyroids—thiopentone	68	4	5.8
Vb. Non-toxic thyroids—thialbarbitone	81	19	23.4
VIa. Toxic thyroids—thiopentone	115	15	13
VIb. Toxic thyroids—thialbarbitone	117	54	46.1
Total	2260	250	11.1

in the different groups of patients. It will be seen that, in every group the incidence of sustained arrhythmia is greater when thialbarbitone is the inducing agent than when thiopentone is used. This was also borne out by the examination of records of 52 patients who had two or more

anæsthetics; of these, four patients were arrhythmic after thialbarbitone but not after thiopentone, but no patient was arrhythmic with thiopentone and not with thialbarbitone.

Table V shows the abnormalities found on electrocardiography; all these patients were intubated and 45 of them had a local anæsthetic infiltration. Table VI shows

TABLE V

Abnormalities found on Electrocardiography

Type of arrhythmia	Type of anæsthesia	
	Thiopentone	Thialbarbitone
Ventricular extrasystoles lasting for 10 minutes	1	4
Occasional auricular extrasystole	–	1
Electrical alternans	1	–
Occasional ventricular extrasystoles	3	–
No arrhythmia	21	21
Total	26	26

TABLE VI

Type of Operation on Cases with E.C.G. records

Type of operation	Type of anæsthesia	
	Thiopentone	Thialbarbitone
Thyrotoxicosis	9	6
Non-toxic goitre	3	7
Abdominal	14	13
Total	26	26

the surgical composition of the two groups. Except for the case showing electrical alternans, the electrocardiogram revealed no abnormality that was not detected by palpation. The sustained arrhythmia in the five cases in which it occurred was found to be due to ventricular extrasystole.

Table VII shows a statistical analysis of the figures. The ratio of the difference of percentages to the standard error of the difference being greater than two in all groups, it is

TABLE VII

Statistical Analysis of Results

Group	% of cases showing arrhythmia		Difference of % (d)	Standard error of difference	$\frac{d}{(S.E.)}$
	Thiopentone	Thialbarbitone			
I.	1.9	11.9	10.0	2.8	3.6
II.	8.6	21.1	12.5	3.4	3.7
III.	2.4	15.7	13.3	3.7	3.6
IV.	7.4	13.8	6.4	3.0	2.1
V.	5.9	23.5	17.6	5.5	3.2
VI.	13.0	46.1	33.1	5.6	5.9

unlikely that the increased incidence of arrhythmia during thialbarbitone anæsthesia was due to chance.

CONCLUSIONS

1. Sustained arrhythmia during the induction is more prone to occur during thialbarbitone than thiopentone anæsthesia.

2. E.C.G. records on 52 cases showed that 5 cases of sustained arrhythmia were due to ventricular extrasystoles.

3. Patients suffering from thyrotoxicosis are more prone to develop an arrhythmia during the induction of anæsthesia by the technique described than normal patients.

I should like to thank the surgeons of the United Leeds Hospitals for access to their cases on whom these observations have been made; to Dr. Glyn Jones for his help in taking the electrocardiograms, to Dr. A. B. Eastwood and Dr. W. S. Suffern for assistance in the interpretation of the records, and to Dr. B. L. Welch for his statistical help.

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GENERAL ANÆSTHESIA FOR ANGIOCARDIOGRAPHY

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INTRODUCTION

Angiocardiography is now accepted as one of the most valuable investigations which may be carried out prior to cardiac surgery. Although it is performed, particularly in America, in a large variety of medical and surgical thoracic conditions, it is used in this country chiefly in the diagnosis of congenital heart disease and as an aid to visualizing the abnormal vessel arrangement before surgery is attempted in cases of Fallot's tetralogy.

This difference in its application probably explains why there is such a divergence of opinion as to the risks of the procedure, and the wide variation in the mortality figures that have been published. This paper reviews the literature on anæsthesia for angiocardiography and then describes a technique which has been used in a series of 50 cases of cyanotic heart disease at the Middlesex Hospital. Apart from two young adults, all these patients have been under 16 years old, the average age being $7\frac{1}{2}$ years, and the youngest being a child aged $2\frac{3}{4}$ years who weighed 20 lbs. (9.0 kg.).

LITERATURE

Robb and Steinberg (1939) reported a series of 127 patients between the ages of 16 and 74 on whom angiocardiography was performed under local anæsthesia; pre-

medication with barbiturate was given only to extremely nervous patients.

Dotter and Steinberg (1951) in a monograph on angiocardiography reported on a further 1,000 patients without a fatality. They stated that heavy premedication is undesirable as its respiratory depression adds to a potentially dangerous procedure especially in cyanotic children, and they mentioned phenobarbital, sodium phenobarbital and sodium pentobarbital as suitable premedication. Small doses of morphine could be used judiciously to control the coughing immediately following the injection; infants were given 2 mg. morphine per 10 lbs. (4.5 kg.) body weight and 0.15 mg. atropine to prevent vagally induced bradycardia or cardiac arrest.

These authors further stated that although the depression resulting from a general anæsthetic may be undesirable, the excitant effect of the angiocardiogram is potentially dangerous in itself, and at least three deaths have occurred from aggravation of pre-existing cardiac failure due to hyperactivity and crying during the procedure. Basal narcosis with 0.2 ml. of thiopentone per lb. (0.45 kg.) of body weight given per rectum combined with local infiltration for the venipuncture did not prevent coughing or movement resulting from the injection. They mentioned isolated cases anæsthetized with agents such as ether given by open-drop or closed circuit, gas and oxygen, bromethol and intravenous thiopentone. They maintained that sparks in the X-ray department made administration of cyclopropane an exceedingly dangerous procedure.

Patients undergoing angiocardiography with local anæsthesia complain to a varying degree of symptoms such as pain in the arm, a burning sensation over the body, dizziness, nausea, vomiting, and generalized weakness. Coughing, transient respiratory arrest, severe hypotension

and shock, syncope and sudden death may occur in extreme cases. Neo-Iopex is said to be safer than Diodrast 70 per cent.

Brocklebank (1948) mentioned that the patients in his and Keele's (1948) series were premedicated with quinalbarbitone or pentobarbitone, followed by a general anæsthetic in the X-ray department using cyclopropane and oxygen in a closed circuit and intratracheal intubation to maintain a clear airway.

Kreuzer et al. (1950) reported 400 cases with one death 12 hours after injection; no general anæsthetics were given and symptoms were noted similar to those described by Dotter and Steinberg and by other authors who used only local anæsthesia.

Anstruther Smith (1950) premedicated his patients with pentobarbitone 0.6 grain per stone (6 mg./kg.) body weight following this with trichlorethylene and oxygen through a Boyle's machine. Apart from one patient who coughed after the injection of contrast medium, he found this form of anæsthesia safe and satisfactory.

Lee (1950) advised nitrous oxide, oxygen and trichlorethylene.

Carnegie (1951) in the most informative paper yet written on anæsthesia for angiocardiography, experienced a death following the use of nitrous oxide, oxygen and trichlorethylene and now induces anæsthesia with cyclopropane and maintains it with cyclopropane and ether in a closed circuit; intravenous procaine 0.2 per cent infusion is given to obviate myocardial irritability and excessive bronchial secretions. The ether is added to prevent breath-holding and bronchospasm which occurred when cyclopropane alone was used. He justifies the use of these explosive agents in the X-ray department by using the closed circuit technique and by placing the anæsthetic apparatus next to

the extraction grille of the air-conditioning plant, so that any gas which escapes is removed from the room. Local 2 per cent procaine is infiltrated round the vein to prevent venospasm. In this series of 172 patients of whom 115 were under general anæsthesia there were 4 deaths, 3 of these being in patients under general anæsthesia.

MORTALITY AND MORBIDITY

Dotter and Jackson (1950) circularized the major hospitals in Great Britain and the U.S.A. and, from the replies, they collected and analyzed the causes of 23 deaths occurring during angiocardiography. The mortality rate in Great Britain was 1: 59 cases and in the U.S.A. 1: 397, the discrepancy being attributed to the fact that the majority of angiocardiograms in Great Britain were done on patients with heart disease.

Of these 23 deaths, 21 occurred in patients with heart disease and 17 of the 23 were in patients under 8 years of age. Eight children died immediately or within 10 minutes of the injection and a further 9 within 3 hours of the injection. Respiratory difficulty or arrest, pulmonary œdema, increasing cyanosis, vomiting, loss of consciousness or failure to emerge from the anæsthetic were observed in those patients who died.

Sixteen of the fatal cases had some form of general anæsthetic such as open ether, nitrous oxide, cyclopropane, trichlorethylene, thiopentone or bromethol. At postmortem the cause of death was seldom discovered but 14 of the 23 cases had a right to left intra-cardiac shunt which makes a direct action of the dye on the medullary centres a possible explanation for the fatality.

PRESENT INVESTIGATION

The series of 94 angiocardiograms which have been performed at the Middlesex Hospital include 50 patients to

whom a general anæsthetic was administered. These 50 cases had a total of 79 angiocardiograms, no patient having more than two injections. Nitrous oxide, oxygen and ether were used in the first few instances, but because of the explosive hazard as well as the indifferent results obtained, these agents were abandoned in favour of the following technique which has been employed in 42 cases. It provides a rapid, pleasant and safe induction with thiopentone, thus avoiding any struggling and consequent increased anoxia which is so harmful to these children. A light level of anæsthesia is then maintained with nitrous oxide, oxygen and trichlorethylene. Immediately before the injection of contrast medium, anæsthesia is deepened considerably for a few minutes by a further injection of thiopentone. This eliminates the undesirable reflexes which may be responsible for the morbidity and mortality figures that have been reported.

Great attention to detail in the anæsthetic technique combined with care in the pre-operative and post-operative management of these cases probably contributed to the fact that there was no mortality and negligible morbidity in our series so far.

EXAMINATION AND ASSESSMENT

A general examination of the patient should be made by the anæsthetist, particular attention being paid to a history of allergy, especially asthma, as such individuals are apt to have reactions to the injection of Diodrast (Crepea et al., 1949). Carnegie (1951) found that a history of attacks of cyanosis or loss of consciousness was of grave prognostic significance.

A poor exercise tolerance and a high packed cell volume (P.C.V.) are warnings of the degree of anoxia that is present, and consequently of a smaller margin of safety in

the administration of the anæsthetic. Patients with a hæmoglobin estimation of 155–176 per cent and a P.C.V. of 75–85 per cent have not been uncommon in this series and have had no reactions from the injection of Diodone.

SENSITIVITY TESTS

The value of sensitivity tests is doubtful. Kreutzer et al. (1950) did not find conjunctival and intradermal tests very accurate. Taylor and McGovern (1943) tested 21 patients and found little correlation between the degree of sensitivity to intradermal tests and the reactions from the intravenous injection of 30–50 ml. of Diodrast. Cooley et al. (1950) reported 3 deaths in 300 cases, in each of which intravenous test doses had given no unusual reactions. In 19 of the 26 fatal cases collected by Dotter and Jackson (1950), sensitivity tests were negative.

Crepea et al. (1949) tested groups of patients and found that those who had positive skin tests were more likely to develop reactions with Diodrast injected for intravenous pyelograms than those with negative skin tests; however, some with positive tests had no reactions and some with negative tests could have a fatal reaction. Significantly, 70 per cent of patients with a combination of positive skin tests and positive allergy history had reactions to Diodrast. They also showed that administration of antihistaminics did not influence in any way the reactions to Diodrast.

The conjunctival test was performed on our earliest cases but was soon replaced by an intravenous test with 2 ml. of 70 per cent Diodone. With one exception, the results were negative. This case is interesting in view of the weight of opinion doubting the value of these tests.

Case History. A child, aged 4 years, weight 29 lbs. (13.2 kg.), haemoglobin 156 per cent, P.C.V. 80 per cent, exercise tolerance 10 yards, was given 2 ml. 70 per cent Diodone intravenously as

a test dose and this was followed by shivering, vomiting and tachycardia. However, the child normally was extremely apprehensive and impressionable and it was thought that the reaction was mostly of nervous origin. It was decided to repeat the test dose under anaesthesia (at that time nitrous oxide, oxygen and ether) just prior to performing the angiocardiogram. Consequently a further 2 ml. 70 per cent Diodone were injected without obvious reactions. A few minutes later, 22 ml. of 70 per cent Diodone were injected very rapidly and this was followed at once by vomiting and by apnoea and a bradycardia which lasted for one hour. Further vomiting occurred later in the ward and this contained altered blood. For the next 24 hours tachycardia and a slight pyrexia were present, but apart from this the patient did not appear any the worse for the mishap, and no signs of cerebral anoxia were apparent.

At no time before or afterwards had this child exhibited any further hæmatemesis and it may be concluded with reasonable confidence that it was a toxic reaction to the Diodone, the initial sensitivity test being a true positive.

PREMEDICATION

Our present practice is to give atropine gr. 1/100 (0.65 mg.) by subcutaneous injection one hour prior to angiocardiography. Rectal thiopentone for sedation has proved ideal for these children; disturbance to the patient is minimal and the usual dose of 1 gramme per 50 lbs. (22.7 kg.) body weight has proved perfectly safe and has never given rise to anxiety in regard to respiratory depression. Twenty-five minutes before the start of the angiocardiogram, the patient is turned on to his left side and the dose of thiopentone is given slowly, about 7–10 minutes being taken for its injection. Within another few minutes, the child is asleep and ready to be wheeled in his bed to the X-ray department.

Before the thiopentone is given, the precaution is always taken of seeing that the anæsthetist is in the ward or within immediate reach; furthermore, the anæsthetist accompanies the patient on his journey to the X-ray department. At no

time has any action had to be taken or even appeared to be necessary, but it is felt that it is a worthwhile precaution.

Premedication in the early cases varied with experience gained and to some extent with the individual preference of the anæsthetist. The first few cases were given rectal bromethol, 100 mg. per kg. body weight; however, the preparation of this solution is less simple than is thiopentone, a preliminary enema is necessary, and the respiratory depression resulting from effective doses rendered an alternative method desirable. Pentobarbital by mouth was given to a few cases, but it is not ideal as it is considered that nothing should be done that could in any way add to the possibility of vomiting; the administration of any oral drug to a child (even without the customary spoonful of jam or sip of fruit juice) may cause active stomach movements and secretion of gastric juices. The possibility of this occurring is enough to condemn oral premedicants in these cyanotic children where every precaution taken is of the utmost importance.

The patients over 12 years of age were given papaveretum and either scopolamine or atropine, but this was not satisfactory for the younger children as safe doses for these poor risk cases did not give adequate sedation. The somewhat formidable appearance of the X-ray department scares them and produces a state of mind that can easily lead to a stormy induction, thereby increasing the oxygen requirements, and to a difficult maintenance which in this procedure may lead to serious consequences.

Prior to the induction of anæsthesia, the only drug given in addition to premedicants is penicillin: 1 hour before operation—300,000 units Distaquaine and 250,000 units crystalline penicillin. Postoperatively 600,000 units Distaquaine are given twice daily for 2 days.

ANAESTHETIC TECHNIQUE

The patient is lifted from his bed on to the X-ray table and placed in the supine position. The vertical position for a cyanotic patient under a general anæsthetic would seem to be fraught with danger. Under the premedication recommended above, these children rarely wake up on being transferred from their beds, an occasional restless turn being the only sign of resentment.

Induction of anæsthesia is with intravenous thiopentone, 5 per cent solution; the dose varies with the child's weight and its response to the premedication but usually 3–5 ml. is adequate. The stimulus of the needle may waken the child momentarily but complete amnesia is present. Following this initial dose of thiopentone, maintenance is with nitrous oxide, oxygen and trichlorethylene. The oxygen percentage in the mixture is kept at 30–40 per cent according to the degree of the patient's debility, and most cases become less cyanosed as soon as the mixture is started. Trichlorethylene has proved very satisfactory and no cardiac irregularities have been encountered. A low concentration is used, the lever of the ordinary Boyle's machine bottle never being put further than the " half-over " mark, the plunger fully withdrawn and a total gas-flow of 6 to 8 litres, according to the child's size. In addition, about 5 ml. of 1 per cent procaine are injected subcutaneously around the vein prior to dissection and insertion of the cannula. This prevents venospasm and also permits the use of minimal general anæsthesia. Commonly the patient pronates his arm in response to the distension caused by the local anæsthetic—an indication of how light the anæsthesia may be kept at this stage of the procedure. If, however, reflex movements become troublesome, anæsthesia may be deepened slightly by a further injection of 1–2 ml. of 5 per cent thiopentone.

A cannula is now tied into a vein in the antecubital fossa, it is connected by a three-way tap to an intravenous drip set and an infusion of a mixture containing 560 ml. of normal saline and 1,000 units of heparin is started at a rate of 3 ml. per minute. Prior to the injection of the estimated dose of contrast medium, an equal amount of saline is injected rapidly through the cannula to ensure that it is firmly in the vein and that there is no obstruction. A dose of 70 per cent Diodone, 1.5 ml. per kg. body weight, is now drawn up and the radiologist prepares to take multiple exposures by a rapid casette-changing mechanism.

At this stage, it is absolutely vital to deepen the anæsthesia considerably in order to avoid the undesirable reflexes which occur on the injection of this large volume of dye. These effects, e.g. vomiting, coughing, bronchospasm and circulatory collapse have been described in the literature reviewed earlier in this paper and their grave danger under general anæsthesia cannot be over-emphasized. Anæsthesia is, therefore, deepened by injecting 2–3 ml. of 5 per cent thiopentone into the drip and then the lungs are immediately inflated with 100 per cent oxygen, the nitrous oxide and trichlorethylene being discontinued during these few minutes. After one minute, word is given for the dye to be injected and manual inflation is discontinued for 10 seconds while the films are being exposed. Although normal respiratory movements do not interfere with the visualization of the contrast medium, it is felt that the slightly deeper excursions of manual inflation might obscure the fields. Once the films have been exposed, inflation with 100 per cent oxygen is recommenced and after 2–3 minutes a return to the nitrous oxide, oxygen and trichlorethylene mixture is made and normal respiratory rhythm is permitted.

If a second view (e.g. right or left oblique) is desired, an interval of 25 minutes must elapse in order to exclude unto-

ward effects from the Diodone. During this time, the anæsthesia is maintained at a very light level with nitrous oxide, oxygen and trichlorethylene. Although the effects are not nearly so marked with the second injection of Diodone, a further injection of 5 per cent thiopentone is given but only 1–2 ml. will be necessary to produce an adequate depth of anæsthesia. Oxygen inflation is performed as for the initial angiocardiogram. As soon as the films have been taken, no further anæsthesia is required and 100 per cent oxygen is administered while the cannula is removed from the vein and the skin sutured. The patient is now returned to bed, the anæsthetist accompanying him to the ward for these patients are liable to sudden cardiovascular collapse; and, of course, they will not tolerate even a brief period of anoxia due to respiratory obstruction or vomiting.

COMMENTS ON THE ANAESTHETIC TECHNIQUE

Induction with thiopentone intravenously after the same drug has been given per rectum is theoretically open to criticism, but in practice, no untoward results have been noticed; it is justified here since struggling, awakening, and anoxia from increased oxygen consumption are avoided which might occur with a nitrous oxide–oxygen induction.

Intubation has not been performed on any of these patients. Although intubation would prevent any laryngeal spasm occurring, an endotracheal tube does not prevent bronchospasm but may even initiate it or, at best, may predispose to bronchial irritability. This fact together with the necessity for deepening the anæsthesia in the early stages merely to permit intubation has outweighed its possible advantages. A suitable small oral airway has proved perfectly adequate for preventing any respiratory obstruction.

Bronchospasm appears to be one of the commonest and most dangerous complications. It produces anoxic anoxia

in a patient unable to tolerate any further degree of oxygen deprivation. Bronchospasm also obstructs the pulmonary circulation thereby diminishing the return of blood to the left side of the heart. This results in a fall in blood pressure and stagnant anoxia and circulatory failure ensue.

Intermittent thiopentone has been given to deepen anæsthesia at the necessary times. Although thiopentone, being a bronchial constrictor, might reasonably be thought to add to the reflex bronchospasm, this has not been the case and complete freedom from respiratory reflexes and from immediate vomiting have been obtained since using this technique.

One hundred per cent oxygen is used prior to the injection of Diodone for the following reasons:

1. To maintain very full oxygenation in anticipation of the shock produced by the injection of the required large volume of Diodone.
2. To ensure that maximum oxygenation is present, thus providing the longest possible time for resuscitation should respiratory or cardiovascular collapse occur.
3. To ensure full oxygenation for the heart, thereby lessening the chance of cardiac reflexes or cardiac arrest occurring as a result of vagal stimuli. Sloan (1951) has shown that these occur particularly in the presence of anoxia. Dotter and Steinberg (1951) interpreted E.C.G. changes in some of their cases as being due to transient myocardial damage, possibly anoxic in nature.

Cardiovascular reflexes are still encountered. A tachycardia develops and the blood pressure temporarily falls. Blood pressure readings have not always been taken as it is quite impossible for the unaided anæsthetist to take frequent blood pressure recordings since the administration of the anæsthetic demands his full attention. About one quarter of the cases had B.P. recordings, and a fall of

between 10 and 30 mm. Hg in the systolic pressure was noted after injection of the dye; the fall in pressure never appeared to be so drastic as is reported by Howarth (1950) and Carnegie (1951). Marked dilatation of the pupils has been noticed in almost all the cases; it does not appear to have an ominous implication and is either due to a direct action of the Diodone or may be part of a generalized sympathetic response. Whatever the cause, it only persists for about 5 minutes; at the same time the pulse rate and the blood pressure begin to return to about their previous levels.

E.C.G. recordings have been made in a small proportion of the earlier cases; no cardiac arrhythmias were ever noted and for the anæsthetist E.C.G. recordings are not a vital accessory. It does, however, make possible an accurate correlation between the time the films are exposed and the exact states of the cardiac cycle, and for this reason is now done as a routine. A total of 24 E.C.G. records were taken; only one of these showed any irregularity in cardiac rhythm, this being during an angiocardiogram on an adult under local anæsthesia, when a few premature beats were noted.

Venospasm has once been so severe in spite of infiltration of local anæsthetic that rapid injection of the dye has been impossible. A supraclavicular brachial plexus block with 10 ml. of 1 per cent lignocaine without adrenaline resulted in good vasodilation and a successful angiocardiogram.

RECOVERY

In view of the fact that the last dose of thiopentone has to be given very shortly before the procedure is completed, it may be as long as 10 minutes before the child responds to painful stimuli, e.g. pinching the pinna; if left undisturbed, these children are quieter post-operatively than if other techniques have been used and it is hoped they will sleep for 1–3 hours afterwards. Although early wakefulness after

anæsthesia is ideal for most patients, it is felt that it is of great benefit to these children, who have had angiocardiograms, to sleep for some time afterwards. Vomiting, which frequently follows angiocardiography, even under local anæsthesia, seems to be minimized by the sedation, and restlessness is avoided at a time when this might seriously prejudice the condition of a cyanotic child already suffering some degree of shock.

On return to bed, oxygen is administered by mask, the child is turned on to its side and the foot of the bed is raised on six inch blocks for some hours as a precaution against aspiration of vomit, and as a means of treatment should there be any evidence of shock.

EMERGENCY FACILITIES

1. Reliable and adequate suction must be available in the X-ray department.

2. A resuscitation trolley must be at hand and on this should be separate syringes ready to be filled with:

(*a*) Cardophyllin 10 ml.
(*b*) atropine sulphate gr. 1/100 (0.65 mg.).
(*c*) adrenaline 1 ml. 1: 1,000.
(*d*) nikethamide 2 ml.
(*e*) Anthisan 50 mg.

Fortunately, in our experience of 94 angiocardiograms performed since 1949, none of these drugs have ever had to be given.

SUMMARY

The literature dealing with anæsthesia for angiocardiography is reviewed. It appears that there are inherent dangers in angiocardiography under general anæsthesia for children with cyanotic heart disease. Unfortunately, these are just the types of patients to whom it is almost essential for an anæsthetic to be administered. Fifty of such cases have

been anæsthetized at the Middlesex Hospital without mortality or morbidity except for one case quoted who was ill for a few hours.

A technique is described which provides rapid, pleasant induction of anæsthesia with thiopentone thus eliminating the danger of restlessness and anoxia during induction. Maintenance is with nitrous oxide, oxygen and trichlorethylene using a high oxygen percentage and a low trichlorethylene concentration so that good oxygenation is ensured and cardiac irregularities due to trichlorethylene are avoided. In order to eliminate dangerous respiratory reflexes, small intermittent doses of intravenous thiopentone 5 per cent are given prior to the injection of Diodone 70 per cent. Post-operative care is stressed and described.

ACKNOWLEDGMENTS

I would like to thank members of the Department of Anaesthetics, the Middlesex Hospital, for the encouragement and the help they have given me, Dr. Walter Somerville of the Department of Cardiology for his very helpful criticism, and Dr. Pattinson of the X-ray Department for allowing me access to his personal notes on some of these cases.

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Brit. J. Anæsth. (1953), **25**, 227

RATIONALIZED NITROUS OXIDE-OXYGEN ANÆSTHESIA

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NITROUS oxide given with 21 per cent of oxygen is a very safe non-toxic, non-inflammable, and non-irritant anæsthetic agent. Recovery from it is almost immediate. In fact the only drawback to nitrous oxide is its lack of potency, which is only about 15 per cent as compared with the 100 per cent of ether (Guedel, 1945).

Why, then, is this agent, which is claimed to be the ideal anæsthetic (Seevers and Waters, 1941), not in general use in cases where its potency is sufficiently great. According to Guedel (1945) nitrous oxide can carry the anæsthesia to a depth which will allow practically every operation apart from laparotomies and pelvic operations to be performed, and this, it is stated, without reducing the oxygen in the anæsthetic mixture to below the normal metabolic requirements. Nevertheless, nitrous oxide *is* a weak anæsthetic, and failure in the technique of its administration may easily result in an anæsthesia which is not deep enough to allow any operation at all to be performed.

In fact, to obtain the optimum results whenever nitrous oxide is the anæsthetic agent, every precaution must be taken to ensure the highest possible partial pressure of the gas in the lungs. Seemingly, omitting to fulfil this requirement is one of the main reasons for failure encountered with nitrous oxide, and this paper deals with considerations of how to obtain the highest possible partial pressure of nitrous

oxide in the alveoli without reducing the amount of oxygen delivered to the patient.

When anæsthetizing with the potent anæsthetics, a higher concentration of the anæsthetic is required to hasten the induction than later during maintenance. In fact quite frequently concentrations are used initially which, if continued for a longer time, would kill the patient. When the desired depth of anæsthesia is obtained, then the concentration obviously has to be reduced to safer proportions. As nitrous oxide is such a weak anæsthetic, this usual procedure must be modified. The highest possible partial pressure which is obtainable can be used throughout, because anæsthesia with nitrous oxide can never be too deep, provided it is accompanied by the same amount of oxygen, as was available to the patient from the ambient atmosphere*. On the other hand, nothing is gained by keeping the patient in a lighter anæsthesia than nitrous oxide can accomplish, because the gas has no side effects either on the tissues or on the normal physiology of the patient. The one and only aim of a nitrous oxide technique is thus simple, viz. to produce in every case the highest possible partial pressure of the gas in the lungs and, for practical reasons, to accomplish this as fast as possible.

EFFECT OF REBREATHING AND DEAD SPACE

Let us first consider the importance of the gas percentage in the mixture delivered *vis-a-vis* the partial pressure of the gas actually inhaled at the mouth. When there is any rebreathing at all in the anæsthetic system, the inhaled mixture will only be of the same composition as the mixture delivered from the machine, if the gases are exhaled in the same proportions, i.e. with the same partial pressures as they

* It is assumed that this was enough to ensure full oxygenation before the patient was anæsthetized, and that conditions have not changed during the anæsthetic procedure.

are delivered from the machine. In practice this means that no rebreathing at all can be permitted, because the exhaled gases must always have different partial pressures from those inhaled; oxygen is always used, and, even after saturation of the tissues with nitrous oxide, the partial pressure of the latter in the lungs will never reach that of the 79 per cent concentration we can allow the patient to inhale. This applies to a semi-closed system. In theory, if we were able to administer nitrous oxide in a closed system, we could add oxygen according to its consumption for metabolic requirements, and nitrous oxide, as much as is necessary for maintenance of anæsthesia. In practice, however, it is well known that this is almost impossible because of the fine control required for the addition of these gases. A variation of the supply of one of the two gases by a few cubic centimetres will change the state of the patient perhaps from hypoxia to inadequate anæsthesia. As a result of these considerations we were led to try and decrease, and even avoid, rebreathing as far as possible.

All rebreathing can be eliminated, of course, by employing an intermittent flow machine which, if no bag is interposed in the system after the gas mixture has left the mixing chamber, acts as a non-rebreathing system *per se*. Also, however, it is possible to ensure no rebreathing with a continuous flow system; the important factor here governing the amount of rebreathing is the ratio of the flow from the machine to the patient's minute volume (Macintosh and Mushin, 1947). Only if the total flow exceeds the respiratory volume per minute will there be a possibility of avoiding rebreathing, that is if the back-flow is not great enough to enter the bag (Molyneux and Pask, 1951). In most arrangements this is, however, impossible. Using the bag-and-mask set-up, it is quite impossible to avoid all rebreathing. This can be easily and practically demonstrated by interposing

an absorber, as in the Waters absorption to-and-fro method. Even with flows very much in excess of the respiratory minute volume, the canister becomes warm, indicating that there is CO_2 in the system, and implying some degree of rebreathing.

Rebreathing will entail, incidentally, not only a lowering of the nitrous oxide concentration, but also a lowering of the partial pressure of oxygen when giving 79 per cent nitrous oxide.

To be sure of avoiding all rebreathing with a continuous flow it is necessary to interpose a non-rebreathing valve, as close as possible to the mouth. This arrangement, in addition to avoiding rebreathing, permits the rapid elimination of nitrogen. It has not all the advantages of a true intermittent flow machine, e.g. economy and breath to breath control of the composition of gas inhaled (Clement, 1951). However, in practice we do not require to change the mixture being administered and intend to maintain it at 79 per cent nitrous oxide and 21 per cent oxygen throughout.

The next factor resulting in rebreathing is the dead space, which is made up of dead space due to the anæsthetic system, and the physiological dead space. It is not possible to avoid this factor altogether, but the dead space should be as small as possible. This means, amongst other things, that the smallest possible masks should be used. It may, for example, be preferable to substitute a nasal mask for the face mask, for in doing this we are reducing the volume of the mask and also by-passing the mouth, thus producing some decrease in the physiological dead space, which helps further to decrease the total dead space. The same applies to the use of endotracheal intubation, where the tube is connected directly to the machine. If the arrangement is correct (that is, the tube is connected directly to the non-rebreathing valve) there will be almost complete

elimination of the mechanical dead space. Reducing the physiological dead space in this way will actually result in an increased oxygen tension in the patient's lungs, though the oxygen flow is kept the same as before the intubation. For example, with a decrease in the physiological dead space from say 150 to 100 ml., then the effective tidal volume will be increased from about 70 per cent to 80 per cent (namely from 350 to 400 ml.). In other words, though the actual flow still only contains 21 per cent oxygen, the patient is now offered the same intrapulmonary tension of oxygen as would be given by more than 23.5 per cent in the flow from the machine when the dead space has not been so reduced.

It may be concluded from the above discussion, that we will never be able to exceed or even reach the partial pressure of nitrous oxide which is delivered from the machine, but if we want to get as close as possible, then it is of importance to avoid any rebreathing in the system, and to try and avoid unnecessary dead space, lest the optimum possible nitrous oxide tension which is attainable be forfeited.

EFFECT OF LEAKAGE IN THE SYSTEM

A contamination of the nitrous oxide-oxygen mixture with the ambient air can only result in a reduction of the concentration of the gases in the system. It is therefore obvious that an airtight system in direction outwards-inwards must be guaranteed, the only leak allowed being at the expiratory valve. This also applies to the intubated patient as far as the space between the tube and the tracheal wall is concerned. If a leak here is permitted, then whether the patient is breathing by his own effort or being ventilated with positive pressure, air may enter the circuit and a diminution of the partial pressure of nitrous oxide

will follow. If, for example, a leak as small as 1 mm. is allowed all round a tube with a diameter of 2.4 cm., then calculation will show that almost 20 per cent of the inhaled gas mixture may be drawn in around the tube. A flow containing 79 per cent nitrous oxide may thus be no more effective than a 63 per cent flow of nitrous oxide in an air-tight system.

EFFECT OF INCREASED PULMONARY VENTILATION, CONTROLLED RESPIRATION AND BAROMETRIC PRESSURE

Up till now we have discussed how to get the highest possible percentage of the anæsthetic gas to enter the patient's respiratory system. Our next purpose is to get this highest possible concentration transmitted to the alveolar air. The patient will do this by breathing spontaneously and, with every respiration, will mix a certain amount of nitrous oxide (as well as oxygen) with the alveolar air. How long it will be before equilibrium is reached between the alveolar air and the mixture inspired will depend partly on the relationship between the alveolar respiratory minute volume and the capacity of the lung, and partly on how fast the nitrous oxide is carried away (absorbed into the blood) from the lungs. A big respiratory volume compared with the capacity of the lung will favour a rapidly established equilibrium.

Practically we are able to influence this process by asking the patient to breathe as quickly and especially as deeply as possible and not, as so commonly practised, by asking the patient to breathe quietly. Because nitrous oxide is non-irritant and the mixture contains 21 per cent oxygen, this hyperventilation is not resented by the patient. Sometimes a patient will overventilate, and acapnœa may result. In this case controlled respiration with big excursions is easily instituted. Assisted or controlled respiration when the

patient is asleep, seems to be a convenient way of hastening the establishment of equilibrium.

When equilibrium between the gases inhaled, the alveolar air and the body tissues is obtained there will be no need to continue further the hyperpnœa but, of course, an air-tight system has to be maintained throughout the anæsthesia.

Quite apart from its use during induction controlled respiration seems to potentiate the effect of a given partial pressure of the anæsthetic gas. It is not finally certain why this should be so. An important factor may be that controlled respiration, even when performed properly, will always result in a mean intrathoracic pressure above atmospheric, which will result in an increased partial pressure of the inhaled gases. As it is the partial pressure of a gas, and not the actual percentage, that determines its absorption and therefore the depth of anæsthesia it produces (Faulconer et al., 1949) this rise, though small, may play a part in the increase of depth of anæsthesia during controlled respiration.

The normal changes in the atmospheric pressure influence the partial pressure of the inhaled gases, and thus the depth of anæsthesia obtained with a fixed percentage delivered from the machine. The significance of this factor is evident from the quite simple calculation which shows that an increase of the atmospheric pressure from 760 to 790 mm. Hg increases the nitrous oxide pressure in a 79 per cent mixture from 600 to 624 mm. Hg, which means that the effect will be equal to that of a mixture containing 83 per cent nitrous oxide at 760 mm. Hg. Calculations likewise shows that a decrease in atmospheric pressure to 730 mm. Hg lowers the effect, so that it corresponds to only 75 per cent nitrous oxide. While these changes in the partial pressure mean nothing with the more potent anæsthetics, they may combine with the other points mentioned to make

the anæsthesia more or less adequate when nitrous oxide is employed. It is therefore not only because of the feeling of wellbeing during fine weather, that it seems easier to give a good nitrous oxide anæsthesia!

In summary, it may be emphasised that because nitrous oxide is a weak anæsthetic, special attention must be paid to avoid lowering of the administered gas tension or, expressed slightly differently, unless all possible pressure increments are made use of to give the highest possible total pressure, the use of nitrous oxide is bound to be disappointing, or supplementation with depressants is apt to be greater than otherwise necessary.

USE OF 1 LITRE FLOWS OF NITROUS OXIDE AND OXYGEN IN A SEMI-CLOSED CIRCUIT

In contrast to the above condition let us discuss in terms of nitrous oxide partial pressures the result of administering 1 litre of nitrous oxide and 1 litre of oxygen per minute during anæsthesia induced by other means, for example with thiopentone and curare. This mixture is selected because of the contemporary popularity of such a technique.

The highest possible partial pressure of nitrous oxide in the lungs ever obtainable with this mixture at atmospheric pressure will be 50 per cent of the available pressure (normally 760 mm. Hg) less the alveolar partial pressures of carbon dioxide and water vapour. This gives a maximum possible nitrous oxide pressure of less than 335 mm. Hg as compared with the 535 mm. Hg with 79 per cent nitrous oxide in the flow. Apart from this relatively low nitrous oxide tension, the time taken to eliminate nitrogen will be prolonged as a result of the rebreathing, and consequently the establishment of maximal blood concentration with nitrous oxide will take longer. The percentage of oxygen actually inspired into the lungs will be lower than that

administered because of the rebreathing, but as equilibrium is approached the partial pressure of oxygen will rise towards that in the mixture being given. Unless hypoxia exists initially there is, however, no evidence to show that more than the normal 21 per cent of oxygen is beneficial (Comroe and Dripps, 1950); therefore, if the comparatively low nitrous oxide tension resulting from this technique means that it is necessary to administer larger doses of central depressants or muscle relaxants than otherwise necessary, it seems irrational to give an oxygen per cent higher than 21.

The term "otherwise necessary" in the preceding discussion is deliberately chosen because, although the technique which has been discussed above achieves the highest possible nitrous oxide tension with any given mixture, it will be impossible in most cases to keep the patient quiet even during those operative procedures which, according to Guedel (1945), can be performed under very light anæsthesia. If the common opinion is valid that flexible anæsthesia is preferable to non-flexible, and an "anæsthetic" with the fewest possible side effects should be used, then it seems rational to let the nitrous oxide play the biggest possible role in techniques combining the use of nitrous oxide and supplements.

A drawback to the nitrous oxide technique proposed here is that the high flow of nitrous oxide increases the gas expenses. With a total flow of about 12 litres per minute, the cost of the gases will be about 10 shillings per hour (calculated in accordance with the price of gases in Denmark). On the other hand, as no rebreathing is allowed at all, the expenses for sodalime are nil, and also those for supplementary agents will be reduced.

POSTSCRIPT

It is an exhilarating thought that if a mixture containing 21 per cent of oxygen and 79 per cent of nitrous oxide is the only one used, then the anæsthetic machine will be a cylinder containing this mixture of gases, a reducing valve, and a flow-regulator. A bag, a non-rebreathing valve, a mask and a syringe or two will complete the anæsthetic equipment.

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Brit. J. Anæsth. (1953), **25**, 237

NITROUS OXIDE-CURARE ANÆSTHESIA UNSUPPLEMENTED WITH CENTRAL DEPRESSANTS

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IN a previous communication (Ruben and Andreassen, 1951) it was stated that it was possible and satisfactory to use only pethidine and curare as supplementary agents to nitrous oxide anæsthesia for major operations, thus avoiding the administration of barbiturates. Applying what is considered a more rational nitrous oxide technique, outlined in a paper by the author (Ruben, 1953) a study was undertaken to evaluate to what extent the use of this nitrous oxide technique may result in avoidance of supplementation apart from the use of relaxants. As a consequence morphine was also omitted in the premedication, which consisted of scopolamine or atropine. It was felt that the role played by a relaxant could more easily be studied when no other supplement was in use.

Forty patients, mostly for major operations, were anæsthetized according to these principles. Nitrous oxide was used in a non-rebreathing system using 20 to 23 per cent of oxygen in the flow delivered from the machine. The rather small number of cases forming the basis for this report is balanced by the consistency of the results, which was good enough to give a clear picture of what was possible with this anæsthesia.

Eighteen of the operations were upper laparotomies, 14 were lower laparotomies, and the rest were thyroid and orthopædic operations. The average duration of anæsthesia

was 164 minutes (longest 455 minutes, shortest 70 minutes). The average dose of d-tubocurarine was 13.9 mg. per hour. In 7 cases gallamine triethiodide was used as the relaxant agent, with an average dose of 66 mg. per hour. Atropine and neostigmine were given in almost every case at the end of the anæsthesia. Apart from occasional hiccoughing, always of short duration, the anæsthesia was satisfactory for the surgical procedure. No other complications attributable to the anæsthesia were encountered during or after the operation.

An anæsthetist entering the operating theatre without knowing which type of anæsthesia was being administered would not have been able to tell the difference from the common thiopentone-pethidine supplemented technique. Most of the time the patient lay quietly on the table. When stronger stimuli were applied, dependent on how curarized was the patient, and the strength of the applied stimulus, the patient could sometimes be seen to move a finger or frown. The reaction was always limited to the time of stimulation.

If the stimulus lasted a long time and no further dose of relaxant was given, then it was observed quite frequently that the reaction ceased—possibly due to adaptation. The amount of relaxant used was, incidentally, of the same order as when supplementation was with central depressants. The patients tolerated extremely well the controlled respiration which in most cases was used during part of the anæsthesia. They even tolerated without adverse effects prolonged continuous positive pressure breathing of the order of 15–20 mm.Hg, which was sometimes used as a test. This seems to indicate that the compensatory circulatory mechanism was still functioning, whereas it is known that patients anæsthetized with other techniques and agents would be likely to suffer a deterioration of the circulation as a

consequence of this procedure. The reaction to blood loss during the operation was interesting. While haemorrhage up to a certain limit did not affect either the blood pressure, the pulse pressure or the pulse rate, an additional bleeding might change this stable picture rather suddenly, indicating that shock was imminent. A comparatively small transfusion, judged to be almost equivalent to the last small blood loss (about 100 ml. for example) was then able to restore the blood pressure and pulse rate to their previous values. This shows a degree of flexibility of the circulatory system unusual in the anæsthetized patient. It is often stated that too light an anæsthesia results in an increase in blood pressure and/or an increase in pulse rate (Stephen, 1952). This has not been observed in this study, even when the patient was reacting with movements to stimuli, although the pulse and blood pressures were followed very carefully during the whole anæsthetic period. In one case pre-operatively where there was a lowered blood volume, the patient after premedication of 0.5 mg. scopolamine, on admission to the operating theatre showed a lowering of the arterial blood pressure from 160/110 to 80/50. This might indicate that the administration of scopolamine is not without effect on the compensatory mechanisms of the circulatory system.

It seemed also that the omission of central depressants maintained fully the reactions of the anæsthetized patient to hypoxia and carbon dioxide excess. The importance of this may be of practical value, as there is good evidence to believe that some of the changes seen in the postoperative period are caused by the unphysiological effects of prolonged carbon dioxide excess during anæsthesia (Miller et al. 1950). Cyanosis during this anæsthetic combination (using approximately 21 per cent of oxygen) will appear very easily if either the respiratory minute volume is

decreased or atelectasis should occur during the anæsthetic procedure. Apart from revealing a lowered oxygen uptake, this also indicates that there may be accompanying carbon dioxide accumulation, whereas a higher oxygen percentage might have hidden this complication. The general clinical impression of the well-being of the patients after this form of anæsthesia may very well be due to these facts.

Immediately after discontinuing the anæsthesia at the end of the operation the patient wakes up, and exhibits an awareness and clarity of mind of quite a different degree to that usual after supplemented nitrous oxide anæsthesia. An indication of how fast the patient eliminates the anæsthetic is that in practically every case he complains almost instantly of pain from the site of the wound. Also, the patients are able to walk with assistance from the operating theatre to their bed. This is even the case after lengthy upper abdominal operations. Thus it has been possible to get every patient out of bed on the day of operation, unless surgical conditions made this inadvisable. The importance of getting out of bed quickly in the prevention of post-operative atelectasis, embolism, gas distension and general debility is generally accepted.

The test we employed to see if most of the relaxant effect had disappeared was to let the patient raise his head and maintain it lifted for about 5 to 10 seconds. If he was unable to do that, then more atropine and neostigmine were administered until this effect was obtained. That ability to perform this test did not, in fact, indicate that the patient was entirely free of relaxant effect was seen from the decreased power in the lower extremities, which the patient presented while walking from the table. This was the real reason why it was necessary to assist the patient on his way from the operating theatre. This debility had

usually quite disappeared before one hour after the end of anaesthesia.

Observations showed the importance of the relaxant for the nitrous oxide anæsthesia itself. Whether real or not, the patient seemed to be much deeper "asleep" with the addition of d-tubocurarine than without. This could be observed during induction, when the relaxant was first added, as well as at the end of the anæsthesia, when the administration of neostigmine to the patient, stabilized with nitrous oxide, apparently lightened the anæsthesia. Also it was seen that the administration of relaxants during application of a stimulus modified the response to it. Whether this indicated a deeper anæsthesia, a breaking of the reflex arc, or was just a suppression of the reaction to stimuli it was not possible to determine precisely. An observation which it has been possible to make during this form of anæsthesia, because the patient was not infrequently maintained at the borderline of reaction, supports the view that anæsthetic depth is a relative term. When the eyelash reflex was tried before, during and after a stimulus was applied, it could be seen sometimes that this was present during, but not before or after the stimulus at the operative site.

In all but one case there was total amnesia to the whole procedure. Objective inquiry immediately on awakening gave in every case the answer that the patient had slept well, without dreaming, and that he was very surprised to hear that the operation was finished. In one case, where the patient thought that he could remember part of the operative procedure, this did not seem to annoy him to any extent. Also in this case there were no changes in blood-pressure or in pulse rate during the course of the anæsthetic. This particular patient showed no response to stimuli during the whole procedure. He was breathing

spontaneously for most of the time, so that total curarization does not seem to be the explanation for this occurrence.

No absolute contra-indications to this method of anæsthesia have been found. It is apparent that cases in which relaxants are contra-indicated or where pre-existing hypoxia necessitates an essentially higher oxygen percentage than 20, this form of anæsthesia should not be used.

SUMMARY AND CONCLUSIONS

An investigation was carried out to see whether it was possible in nitrous oxide-oxygen anæsthesia to limit supplementation to a relaxant and to avoid entirely additions of central depressants. It was found possible in every case to secure an anæsthesia that was satisfactory to the patient, the surgeon and the anæsthetist. In fact the picture of this anæsthetic could not be distinguished from nitrous oxide anæsthesia, where supplementation with barbiturates and pethidine is used. It therefore seems as though this supplementation is mostly used to " cover " the weak effect of the gas during the saturation period and perhaps sometimes also to add to the effect of the gas when it is used at a lower partial pressure than in this series of cases. It was, however, also the impression that the use of the relaxant itself was part of the reason why other supplementation could be discarded. Yet, the amount of relaxant used was of the same order as when central depressants were employed.

As a result of this study it is concluded that in suitable cases this method of anæsthesia should be taken into consideration as a worthwhile alternative to other methods.

ACKNOWLEDGMENT

The author is indebted to Dr. Lucien E. Morris, of Iowa University Hospital, Iowa, who demonstrated to him that it was possible to omit central depressants in nitrous oxide anæsthesia.

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Brit. J. Anæsth. (1953), **25**, 244

INTRAVENOUS PETHIDINE IN ANÆSTHESIA

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THIS paper is written in an attempt to assess the value of intravenous pethidine as an adjuvant in anæsthesia. With this end in view, it was decided to use a control series. In 200 consecutive patients for surgery, pethidine was used in alternate cases. All the administrations were by the same person.

TECHNIQUE

As premedication, most adult patients received papaveretum gr. 1/3 (20 mg.) with scopolamine gr. 1/150 (0.4 mg.). For those over sixty years of age the scopolamine was replaced by atropine gr. 1/100 (0.65 mg.). Patients under 20 years of age and others who warranted a departure from the above scheme received premedication as seemed indicated.

Induction of anæsthesia was carried out with soluble thiopentone 300 mg. or less in 5 per cent solution. An oropharyngeal airway was then inserted in the majority of cases. In those who required it, intubation was performed under direct vision after the injection of gallamine triethiodide and spraying of the vocal cords with 10 per cent cocaine solution.

Maintenance was with nitrous oxide 6 l. and oxygen 3 l. per minute; this flow was reduced after about ten minutes to nitrous oxide 2 l. and oxygen 1.5 l., " blowing off " with carbon dioxide absorption by Waters' canister. When relaxation was needed, gallamine triethiodide was used for

the purpose and was given in doses sufficient to satisfy the surgeon's demands.

In all cases for operations on the stomach or duodenum (43 of the 200) in addition to the above, costal margin block and splanchnic block were performed, the latter either by the posterior route in the anæsthetic room or by the anterior route after opening the abdomen. The solution used was amethocaine 1: 2000 with adrenaline 1: 400,000. These procedures were carried out on the unconscious patient.

Where pethidine was not used, the nitrous oxide was supplemented by thiopentone injected intermittently.

The scheme of administration of pethidine for the first half of the series (50 cases) was similar to that described by Mushin and Rendell-Baker (1949). Twenty-five mg. of the 1 per cent solution, which was used throughout, were injected slowly when anæsthesia was stabilized, followed by further injections of up to 25 mg. at intervals of not less than 20 minutes. It was found, however, that this dosage did not produce satisfactory anæsthesia in a proportion of cases and supplementary doses of thiopentone were often needed. In the second half of the series, therefore, the initial dose of pethidine was raised to a maximum of 50 mg. and was injected before the induction dose of thiopentone.

The timing of further injections of pethidine was determined by movements of the patient's extremities, by phonation or by a rise in the pulse rate, bearing in mind that the full effect of pethidine may not be exerted for up to ten minutes (Blazeby, 1951; Griffiths, 1950).

The composition of the groups, those receiving pethidine and the control cases, were very similar in regard to the types of operation performed. More than half of the patients underwent laparotomy; the few intrathoracic operations included were on the stomach, œsophagus and sympathetic chain. The average age of the patients in the

two groups was 44 years in those receiving pethidine and 46 in the controls, ranging respectively from 11 to 84 and from 12 to 88 years.

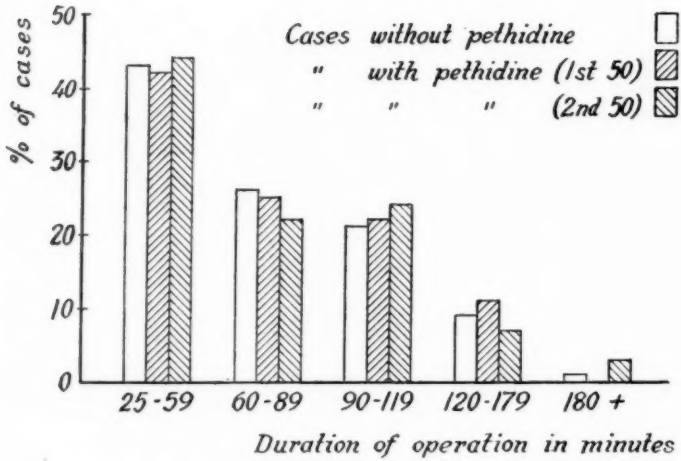

FIG. 1

Since a significant difference between the groups in respect of the duration of the operations included could introduce a high degree of error into the interpretation of the results, a histogram (fig. 1) has been prepared.

The mean durations were 73, 77 and 72 minutes respectively.

RESULTS IN CONTROLLED SERIES

Dosage

The figures (table I) reveal a difference in thiopentone dosage between the pethidine cases and the controls with a high degree of significance. With respect to total dosage, the differences are both greater than six times the standard error of the difference.

TABLE I
Dosage of thiopentone

	Total dose (mg.)				Rate of dosage (mg./min.)			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range	Standard Deviation
Controls	100	785	250–1600	220	100	12.0	2–32	5.5
Pethidine (first half)	50	597	200–1000	115	50	9.7	2.2–22.5	4.3
Pethidine (second half)	50	412	250–1050	140	50	6.4	1.7–12.2	6.4

The differences in the dosage of gallamine (table II) are not significant in no case exceeding two and one-half times the standard error of the difference.

TABLE II
Dosage of gallamine triethiodide

	Total dose (mg.)				Rate of dosage (mg./min.)			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range	Standard Deviation
Controls	78	82	30–180	48	78	1.2	0.4–2.5	0.33
Pethidine (first half)	36	95	20–180	52	36	1.4	0.3–2.7	0.44
Pethidine (second half)	34	83	40–130	26	34	1.1	0.6–2.2	0.48

The differences shown for the doses of pethidine (table III) are, of course, highly significant, both exceeding twelve times the standard error of the difference.

TABLE III
Dosage of pethidine

	Total dose (mg.)				Rate of dosage (mg./min.)			
	No.	Mean	Range	Standard Deviation	No.	Mean	Range	Standard Deviation
Pethidine (first half)	50	76	25–130	7.8	50	1.0	0.3–1.5	0.15
Pethidine (second half)	50	102	30–200	10.5	50	1.4	0.8–2.7	0.51

Recovery of consciousness

Previous writers (Blazeby, 1951; Griffiths, 1952; Johnson, 1951) have stated that the recovery of consciousness appears to be more rapid when pethidine is used than when nitrous oxide and oxygen are supplemented by other agents. This series bears out their impression. Of the 100 patients who received pethidine, 56 were able to respond to simple commands before leaving the theatre, compared with 32 of the controls. The difference between the proportions responding (24 per cent) was more than three times the standard error of the difference, 7 per cent, and therefore significant.

The pethidine patients were found to be, in general, the more co-operative on reaching the ward.

Post-operative pain

The time of onset of post-operative pain was gauged by the time at which the first dose of analgesic drug was needed. The mean time after leaving the theatre was 7.7 hours among the patients to whom pethidine had been given (range 0–20 hours) and 6.0 hours among the controls (range 0–23 hours), excluding those patients who received no such drugs. This difference proves not to be a significant one (p greater than 0.1).

Post-operative vomiting

The criterion of post-operative vomiting used was the patient's own statement, as the writer feels that vomiting after operation is important today rather as a source of distress to the patient than as a danger to health or survival. No cases of truly severe vomiting were encountered. Excluding those patients who awoke with a Ryle's or similar tube in place, the figures were:

Vomited	Pethidine	No pethidine
" Not at all "	42	53
" Once only "	12	9
" Several times "	6	2
" Severely "	3	0
	63	64

The difference between the proportions in the two groups who did not vomit (16 per cent) is greater than three times the standard error of the difference, 4.9 per cent, and therefore significant.

Post-operative complications

This series is too small to draw any conclusions regarding the incidence of complications.

Three patients in each category died within 2 weeks after the operation. Of these, 4 (2 in each group) were aged patients undergoing major surgery; the other 2 deaths were in younger patients but unrelated to the anæsthesia.

Lobar or lobular collapse was met in two patients from each group; " pneumonitis " in two receiving pethidine and one of the controls; and a small pulmonary embolism was diagnosed in one patient who had received pethidine.

Venous thrombosis following intravenous infusions and wound infections of varying degree were met in approximately equal numbers in the two groups.

Complications during operation

These differed in the two groups.

(*a*) *Cases receiving pethidine.* Respiratory depression, presumed due to pethidine, was seen in nine cases. The depression was one of rate rather than of depth (Blazeby, 1951; Griffiths, 1950). In most of these cases it was deemed necessary to assist or control respiration, even where no relaxant had been used.

Pethidine "phlebitis" was met 11 times in the 100 administrations. It varied in severity from a skin wheal extending a short distance along the course of the vein used for injection (Pearce, 1951; Zuck, 1951) to a dull red line, resembling lymphangitis in appearance, over most of the forearm or leg veins, accompanied by a wide "flare". There appeared to be no systemic accompaniment of the phenomenon and in no instance could any harm subsequently be attributed to it.

(*b*) *Cases not receiving pethidine.* Hiccough occurred during two partial gastrectomies. It was found that this was quickly relieved by a small dose of pethidine given intravenously. Since completing this series, however, although about twenty cases of hiccough have been thus relieved, one has failed to respond, during a partial gastrectomy being performed under nitrous oxide and oxygen anæsthesia with a suxamethonium (Scoline) drip.

Severe hypotension was encountered in three instances. In one case it was attributable to blood loss; all three responded well to resuscitative measures.

Apart from that due to gallamine, respiratory depression was seen once only and in that case was thought to be due to over-premedication.

DISCUSSION

Neff, Mayer, and Thompson (1950) describe an admirable technique in which anæsthesia is induced slowly with nitrous oxide and oxygen after preliminary oxygenation of the patient. It was not, unfortunately, found possible to reproduce this somewhat time-consuming method as a routine in a busy general hospital and recourse had to be made to thiopentone for induction. It is of interest, however, that these authors state that with their technique the doses of pethidine required are notably smaller than when

thiopentone is used, presumably due to earlier saturation of the tissues with nitrous oxide.

Intravenous pethidine does not appear to carry any special risks. On occasion it depresses the respiration profoundly and, despite opinions to the contrary, the writer believes that this depression sometimes necessitates manually assisted or even controlled respiration. The complication is less frequently met with more experience of the method. The most effective preventive measures appear to be slowness in injection and the use of dilute solutions, as recommended by Dunbar Johnson (1951).

The "phlebitis" sometimes seen may be alarming in appearance and extent, but it usually disappears within twenty minutes and no untoward results seem to follow. It has been shown that in the cat pethidine can release histamine in effective amounts (Schachter, 1952), and this may be the reaction responsible. The writer has confirmed that intradermal pethidine produces a triple response in the human subject, both anæsthetized and conscious (Nasmyth and Stewart, 1950). Finer and Partington (1953) discuss pethidine "phlebitis" at length. They quote considerable experimental evidence that the condition, is, in fact, a manifestation of histamine release in the skin.

Recovery of consciousness is somewhat more rapid when pethidine is used than with thiopentone. Post-operative analgesia persists for the same length of time or even slightly longer. The pethidine patient tends to be a more co-operative one in the first hours.

Post-operative vomiting is a little more frequent where pethidine has been used, as would be expected from its known capacity to cause nausea or even vomiting in the conscious subject by whatever route it is administered.

This series has produced no case of hypersensitivity to

pethidine such as have been described by others, nor has the writer seen any such reaction.

The advantages of the technique lie in the quick recovery of reflexes and of consciousness after operation; the comparative rarity of prolonged restlessness; and the facilitation of early post-operative "shake-up" therapy by the co-operation and euphoria of the patient. The goal of minimal administration of specific drugs is brought nearer by this technique.

ACKNOWLEDGMENTS

I desire to acknowledge the encouragement of Miss N. K. Priestley, senior Anæsthetist to St. James' Hospital, Balham, and to thank her for her permission to undertake this investigation. My thanks go also to the surgeons who allowed me to use their cases and to those members of the nursing staff of St. James' who assisted me in collecting the results. I have pleasure in acknowledging my indebtedness to Dr. J. Knowleden for his help in the interpretation of the statistics quoted.

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ON THE INHALATION OF THE VAPOUR OF ETHER IN SURGICAL OPERATIONS

By JOHN D. SNOW

(*Continued from page 169*)

Having considered the state of etherization, and the apparatus and kind of ether to be used, we may now proceed to the mode of conducting the process of inhaling, and the points to be attended to in order to insure its constant success.

I am not aware that any state of the patient with respect to age, constitution, or disease, positively contra-indicates the use of ether during a surgical operation. The patients to whom I have given it have been of all ages, from early childhood to nearly eighty years—six of them being upwards of seventy. They have been in the most different states of general health; two or three had symptoms of tubercles in the lungs; one, of whom I shall speak afterwards, had extensive disease of the heart; two or three had been subject to attacks of congestion of the head, and yet there have been no ill consequences from the ether in any case, and not even any unpleasant effects to counterbalance its advantages, except sickness and vomiting in a few instances. There are, however, certain states of the body in which ether sometimes acts less pleasantly and favourably than in others; but it fortunately happens that these are the states in which we seldom find patients who require surgical operations. Persons in robust health are sometimes less promptly and easily made insensible than others, and are more liable to excitement in the second degree of etherization, and to struggling in the third degree, and also

to have a headache after the ether. Such persons, however, do not often require even a trifling operation, and if they do so, a little abstinence and purgation will place them in favourable circumstances for ether, if they wish to have it. And, if a person in robust health should require an operation on account of an accident, the temporary depression consequent on the injury, and, usually also, loss of blood, would serve as a preparation. On the other hand, insensibility is induced with great ease in persons debilitated by long illness, and in children under all circumstances. Children are, indeed, amongst the most favourable subjects for ether, recovering from its effects as promptly as they are brought under its influence, and it possesses more than the usual advantages in their cases, as, without it, their struggles would often interfere with the performance of the operation.

A full meal causes a temporary plethora, and it has seemed in several instances to render the operation of the ether less easy. It is attended, also, with the further unpleasantness, that vomiting often takes place when inhalation follows it. The best preparation for the ether is, probably a sparing breakfast, or luncheon from two to four hours previously, and a person should never begin to inhale with his circulation quickened by exercise or any kind of exertion.

The water-bath of the apparatus should be three-fourths filled with water, or, at all events, sufficient should be put in to come fairly in contact with the ether chamber, which may as well be fixed in its position in the bath before the ether is put in. The temperature which seems most suitable is about 60°. I do not think it ever necessary to raise it above 65°. In winter a little hot water requires to be added, to elevate the cold water of the patient's room to the required point, but, in hot weather, the water is often 70°

or upwards, and its temperature requires to be lowered, which may be done by mixing spring water with it. Or, to save time and trouble, the operator may be provided with some sal-ammoniac and nitrate of potash, powdered, and mixed together in equal parts; three or four ounces of which mixture being dissolved in the water in the apparatus, will depress its temperature about ten degrees. At the heat I have mentioned, the air will exceed in quantity the vapour, in the mixture the patient breathes; and although it is desirable to induce insensibility as rapidly as possible, this is better than giving the vapour stronger, for a greater quantity will generally be inhaled in a given time than if it were more concentrated, since, when it is too strong, it either excites coughing, or causes the patient to hold his breath. The indication is to give as much vapour in the air as the patient can be got freely to breathe; and 90 parts of vapour to 100 of air—nearly 47 per cent.—is usually about this limit. It must not be supposed, in any case, that because the air of the apartment is of a suitable temperature, the use of the water-bath may be dispensed with; for the vaporization of the ether in the inhaler would cool the apparatus and the air passing through it: less and less ether would be taken up, and at the time when the full strength of the vapour is most required, the patient would probably be breathing air of a freezing temperature, with very little vapour in it.

The tube and face-piece can be screwed on in readiness, and just before the inhalation the ether may be put in. Two ounces, or two ounces and a half, is the quantity I generally introduce, and I always measure it, and again measure what is left at the end of the operation. The quantity of ether required to produce complete insensibility, is, usually, from six drachms to one ounce in the adult, and, in children, in the same proportion, according to their size; and the

quantity required to keep up insensibility during the operation is seldom greater than that which induced the state of etherization. (4)

The position of the patient during inhalation is a matter worthy of consideration. In nearly all capital operations, the position which the surgeon would select, independently of the ether—viz. on the back, with the head supported on a pillow—is a very favourable position for inhalation. For operations on the anus, the patient has to lie on the side, with the knees drawn up, as it would be impossible for him to stand, or even to kneel, and lean over a chair or table, when insensible; and the recumbent posture, I believe, is as convenient for the surgeon, and would be at least equally so for the patient, even if he had to suffer the pain. Sitting upright in a common chair is not a good position for inhalation, and should, therefore, if possible, be avoided. It has answered very well in a number of cases, but on two or three occasions caused some difficulty; either from the patient, when insensible, having a tendency to slide off the chair, or from his stretching his limbs out, in the second or third degree of etherization, when it became impossible to keep him seated. If the patient is obliged to be seated, a chair with a high back, to rest the head against, is the best seat. The dentist's chair answers very well for his operations, as the patient is partly reclining, and has the head supported.

It is generally the best plan to place the patient before inhaling, in just the position that will be suitable for the operation, that there may be no delay when insensibility is induced. Sometimes, however, the patient may be first rendered insensible, and then moved, especially when moving causes great pain, as in some cases of diseased knee. The tourniquet, or the bandages for lithotomy, can be applied whilst the inhalation is going on, but the surgeon

should have all his instruments in readiness before the inhalation.

The apparatus being prepared, should be placed on a small table, or a chair, or on a corner of the operating table, near the patient's head, and the assistant, who administers the ether, should stand on the opposite side of the patient to that which the operator will occupy. The face-piece should be moulded to the features, with the expiratory valve turned to one side, so that the patient may breathe scarcely anything but air at first; and then the valve should be turned a little at each inspiration, gradually to cover the opening, and by this means to cause the etherized air from the apparatus to be admitted by degrees, to the exclusion of the external air; in order to prevent the irritation to the air-passages which would generally arise from the sudden access of air strongly charged with vapour of ether. As the vapour is less irritating to the mouth than the nostrils, it is advisable to request the patient to breathe by his mouth at first. With the face-piece here recommended the patient has no difficulty in learning how to inhale; he merely has to breathe as if it were not on his face, and it offers no obstacle to his doing so. The pungency of the vapour is often complained of at first, even when it is admitted in this gradual way, but the larynx soon comes to tolerate it, and the external aperture can generally be quite closed by the valve, in from a quarter to half a minute. If the patient holds his breath, or coughs, it is sometimes necessary to delay closing the opening for the admission of external air, a little longer, or to open it again for a moment after it is closed; but it is to be recollected, that as the ether produces its effects on the nervous system, it allays the irritability which at first obstructs the respiration of it, and in the meantime the patient must be encouraged to persevere. He soon loses his consciousness of what is going on around, and

enters into the second degree of etherization—often by the time that the etherized air can be admitted of its full strength, and generally within a minute or two afterwards, and he usually becomes quite passive if he has not been so previously. It now and then happens, however, that the patient becomes somewhat excited at this stage of the proceedings, and talks, or sings, or laughs, or cries, and wants to move. In such a case he must be kept quiet, and the face-piece must be kept applied, even although he tries to get rid of it; for it would be wrong any longer to pay attention to his apparent desires, when he is not in a conscious and rational state. I have not met with any instance in which the patient could not be kept inhaling, with the assistance of somebody to hold his hands, and perhaps to assist in steadying his head; and as I do not think that it would ever be proper to make a patient insensible with ether without the presence of a third person, there can never be any difficulty in this stage.

I understand that the ether has often been left off, and given up as a failure, on account of the excitement produced by it, under an impression that it was producing an opposite effect to its usual one, and acting as a stimulant instead of a sedative. Guided by a few experiments on small animals, made in January, I acted on the principle that there is no person who cannot be rendered insensible by ether, and looked on the excitement as the occasional result of the cerebral functions being disturbed by a quantity of ether insufficient to suspend them altogether. If the patient goes on breathing the ether, we may rest assured that he will soon become quiet; especially, if he begins to breathe deeper, as often happens during the state of excitement, when a few inspirations make him quite passive. It can scarcely be required to interrupt the process unless the patient should hold his breath, but if he do, the

face-piece should be removed, or the valve opened for a moment, and the process then resumed again. It is consolatory, however, to know that if one is obliged to desist, insensibility will often be induced, on the process being resumed, without any excitement or struggling. It is advisable to begin again as soon as the patient is calm, and, if possible, before he has relapsed into the first degree, or he will perhaps want to make a long speech. I prefer always to go on without stopping, and let the ether subdue the excitement it has produced. I have always succeeded in making the patient quite insensible, except on one occasion, and then the ether was given up, not from any doubt of its producing its usual effects, for it had made the same patient insensible a day or two before; but, from a fear on the part of Mr. Cæsar Hawkins, who was about to operate, that the struggling might recur during the intended operation—one of unusual difficulty and danger—the removal of a large ovarian tumour. The ether caused a kind of hysterical paroxysm in this woman; she was more violent than any, except one, other patient that I have seen, and the difficulty was increased by the circumstance of the ether being exhibited by a tube in the mouth, whilst, after losing her consciousness, she made efforts to breathe by the nostrils. As she was unwilling to undergo the operation without ether, it was not performed.

Struggling or resistance of any kind, in the second degree, is an exception; the patient generally, as I have stated, remains quite passive after losing his consciousness, and a person inexperienced in the effects of ether may suppose that he is fit to be operated on; more especially if, as often happens, the limbs are quite relaxed. I have often heard a medical man say, on lifting a patient's arm and seeing it drop down again, " the muscles are quite relaxed, he is under the influence of the ether now,"—at a time

when the state of the muscles merely depended on volition not being exerted on them, and when a cut would, undoubtedly, have roused a vigorous resistance.

In the earlier cases I used to raise the eyelid to look at the pupil. I was not able to learn much from it, as generally it is not much altered from its natural state, and remains more or less sensible to light in all stages of etherization; but I soon found that the eyelids furnished very good information with regard to the state of the patient. In the second degree of etherization the eyelids have lost none of their sensibility; on touching them, indeed, the eyes are often moved in an evidently voluntary manner, and any kind of voluntary motion shews that the effects of ether have not extended beyond this degree. (5) The breathing in this stage has not altogether lost its voluntary character, and it is often like the breathing in sleep.

The moment when the patient passes from the second degree to the third, is not always clearly distinguishable, but that is of no great consequence, as it is only mistaking between the second and fourth degrees that would be of importance. Generally, however, the transition can be distinguished. If there has been any kind of voluntary act —as raising the hands, or repeating a word, or making a singing or humming sound—it is discontinued; or, if the eyes have been moved about, or the eyelids lifted spontaneously, these actions cease. If the patient has been perfectly passive in the second degree, a state of slight rigidity of the limbs often marks his passage into the third. The eyelids retain their sensibility, and are closed again on being lifted with the finger, but no voluntary motion is occasioned in them or the eyes, and there is not a resistance offered to their being opened, as there often is in the second degree. If the patient has been breathing steadily for three minutes with the valve closed, or for two minutes if a

child, an operation not requiring a nice dissection may generally be commenced in half a minute after etherization has reached this degree, without waiting for any other signs than those mentioned; but he should be held steadily, as possibly he might otherwise flinch a little at the first incision. If there is any doubt about the patient's condition, it is preferable to wait a little longer till the excito-motory action of the eyelids diminishes, or till the breathing is decidedly automatic, or accompanied with a tendency to snoring, or till the countenance is somewhat altered, which is sometimes the case before the eyelids are quite passive. The face-piece affords a facility for seeing the features which the mouth-tube and cushion did not possess, as it can be removed and re-applied in a moment, and without the process of inhalation being interrupted, if it is done during an expiration. If the countenance is altered,—as, if it were paralysed more or less,—the operation may always be begun; although it is by no means necessary to wait in every case for this symptom. The practice, I believe, is occasionally resorted to, of pricking the patient to ascertain whether he is insensible: there is no harm in it, but I consider that it would be inconclusive where it furnished only a negative result; and I never adopt it, as I constantly observe that there may be insensibility to a slight lesion—as a suture in the skin, for instance—at a time when a greater wound would cause signs of pain.

If, instead of a quiet passive state, there is struggling, or great rigidity of the limbs in the third degree, it is necessary to wait for the next degree—that of complete relaxation—before the operation is begun. The involuntary struggling is now and then considerable in the third degree,—in one case, to be subsequently mentioned, resembling an epileptic paroxysm, the patient, however, being subject to epilepsy. There is occasionally also a rigid state of the whole body,

which, in one instance, took the form of opisthotonos, but the patient, a boy, was heated and out of breath, when he began to inhale, by exerting himself for some time previously, in opposition to the traction by pullies which was used in attempting to reduce a dislocation of the hip. If the patient goes on breathing steadily, however, he very quickly becomes passive, and lies still. The only circumstance which can cause any difficulty is his holding his breath, which he sometimes does, not from the pungency of the vapour, as in the earlier stages, but, apparently, from spasmodic contraction of the muscles of respiration. In two or three cases the breathing was interrupted till the face became quite purple, but the patients soon went into the fourth degree, on its commencing again with deep and quick inspirations. If the skin becomes inclining to purple, the face-piece may be removed for half a minute, if it is thought proper, for the patient to breathe unetherized air until the skin resumes its usual colour; but there need be no alarm, as the breathing always becomes extremely regular when the next degree is attained, and the inhalation need never be given up at this stage, as there can be no danger from ether when the limbs are rigid; and it is better not to begin the operation till the respiration becomes equable and regular, but to wait for the fourth degree in all cases in which the third is at all unfavourable.

There are never any strong demonstrations of pain in the third degree, and a number of surgical operations may be performed without carrying the etherization further,—generally, without any symptoms of pain,—but, in some cases, with the result of a little flinching or moaning, and perhaps a contraction of the features. These very slight tokens of obscure sensation, of which the patient knows nothing, and which do not at all interfere with the operation, may, however, be disregarded when they do occur.

If the inhalation has been continued, and the operation deferred on account of movements or rigidity, the latter may be commenced as soon as the patient becomes still, and his muscles relaxed. If there is the least approach to snoring, whether there is complete relaxation of the muscles or not, the operation may always be commenced, and judging by what I have seen, will never elicit any signs of sensation.

If the operation does not involve the mouth or nose, I am in the habit of continuing the inhalation until after it is commenced; and, if there are any obscure signs of pain, for a little time longer, until they subside. But if the operation has no effect on the patient, I either remove the face-piece, or open the expiratory valve a little way to dilute the vapour. If there is the least snoring I always leave off the vapour entirely, even without waiting for the commencement of the operation when I have requested that it may be begun. The snoring now and then increases for a quarter or half a minute after the inhalation is left off, the breathing becoming deep, accompanied with heaving of the chest, and sometimes also blowing of the lips; but this stertorous breathing always subsides again in a minute or two, and need therefore excite no alarm; it should, however, always be looked on as an indication for discontinuing the ether for a time. It is not possible always to avoid having the breathing somewhat stertorous; for in some patients, no sooner does this kind of breathing subside, than symptoms of pain from the operation begin to appear; and no sooner are these symptoms removed again by the ether than the stertorous breathing re-appears. I have, however, never known it to leave any cerebral symptoms afterwards.

The inhalation having been discontinued during an operation, the time of resuming it must depend on circum-

stances. If any important steps of the operation are going on, it is advisable to anticipate the return of sensibility to pain, and to resume the inhalation so soon as returning sensibility of the eyelids, or any voluntary motion in them, shews that the patient is returning to the second degree. If only some secondary part of an operation—as the tying of arteries—is going on, we may wait till there is some sign of the operation being felt before resuming the inhalation, and it will remove any such sign in a very short time; it being seldom necessary to continue the inhalation more than half a minute, or a minute at the furthest, if the valve is closed, and the vapour of full strength, when it is resumed during an operation, after insensibility has been previously induced. There is very seldom any struggling in the third degree as it succeeds to the fourth; but if there is, it may then be necessary to give more ether to keep the patient in the fourth degree for some time; not because he would feel pain with a less degree of etherization, but because he would not be sufficiently still. Some patients begin to show signs of feeling the operation before there are any other tokens of sensibility, or of ideas, or any voluntary movements; but very often the patient may be allowed to return to the second degree, and to remain some time in it during the operation without shewing signs of pain. Most usually the only sign that he is in this degree is voluntary motion in the eyes or mouth; but, occasionally, the patient talks during the latter part of the operation in a way that shews he is dreaming. If he does not offer to move at the same time, that is not a reason for giving more ether; but if his conversation shows that his dreams are of an uneasy nature, and if he moves about, the inhalation should be resumed if the operation is not completed. Indeed, uneasy dreams—as of quarrelling or misfortunes—during an operation, may proceed from the operation itself, and words

of anger or distress may follow each cut; but when the patient is talking about pleasant or indifferent subjects, it is very evident that he is not in pain.

Insensibility to pain may be kept up for a long time without risk, by allowing partial recovery from the effects of the ether occasionally. I lately kept an elderly gentleman quite oblivious for two hours and a half after Mr. Liston had applied a thick paste of chloride of zinc to a large ulcerating tumour on his face. Each time that he began to feel the smarting the ether was resumed,—at first, after intervals of ten minutes; then, of a quarter of an hour; and finally, of twenty minutes; the recoveries becoming each time more complete before the pain recurred. But the patient had no recollection of them, for each time that he recovered his consciousness, he asked if Mr. Liston had gone without applying the caustic. At the end of two hours and a half, having been allowed to recover more completely than before, he considered that the pain was not more than he could bear, and the inhalation was not resumed. Five fluid ounces of ether were used, and no effects of any kind followed it, unless that the pain, for some hours, was not so great as it probably would have been.

The ether often occasions an increased flow of saliva after it has been continued for a few minutes; it is therefore well to be provided with a towel to wipe the patient's mouth, and the valves of the face-piece, if they get wet, as they would otherwise act not quite so easily. In the third and fourth degrees the saliva would merely flow from the patient's mouth, but in the second degree he is capable of spitting it out.

In operations on the mouth and nose, the inhalation of course has to be discontinued before they are commenced; but the operator should begin the moment the face-piece is removed, in order to take advantage of the full effects of

the ether. In operations attended with no great loss of blood, as the removal of polypi from the nose, and the extraction of teeth, the inhalation can be resumed at any moment, if the sensibility returns before they are completed; but operations attended with the division of the blood-vessels cannot be interrupted; and therefore it becomes desirable to induce a state of insensibility that will last to the end of the operation. If etherization is carried to the fourth degree, complete insensibility usually continues for three minutes after the inhalation is discontinued—sometimes, indeed, for a longer period; but its continuance may generally be depended on for three minutes. This period will allow of the performance of the operation for hare-lip, and some others; and a state of unconsciousness usually lasts above five minutes longer, a period during which any pain there might be would not be remembered afterwards. In the third degree, the muscles which close the jaws are often contracted, but in the fourth degree the mouth falls open; but I do not consider it necessary, on that account, to carry etherization as far as the fourth degree for the extraction of a tooth; for an assistant can easily open the mouth by taking hold of the chin, and recovery is more speedy when the effects of ether are not carried beyond the third degree. When the dentist wants the mouth cleared of blood, he should use a small sponge, as the patient cannot wash out his mouth when insensible.

In all the cases I have witnessed, the patients have recovered their mental faculties very promptly and completely after the conclusion of the operation,—generally within a few minutes,—and in two or three cases only has the period of recovery been delayed for half an hour. I do not think that any thing is ever required to promote the return to sensibility. When the patient is sufficiently

etherized to feel nothing of a surgical operation, he is far beyond the reach of stimulation by ammonia, cold affusion, or any thing else; and when he is so far recovered that these things would make an impression, there is not long to wait for his complete recovery. Elderly people are slower in recovering than young ones; as their respiration is less active, and the ether takes a longer time to evaporate in the breath. For the same reason, if sickness has been caused by the ether, the patient is longer in recovering, as it depresses the respiratory movements.

Although many patients recover their consciousness at once, as out of a natural sleep, yet there is often a short period during which the mind wanders as it is reviving from its temporary suspension; and during this time it is advisable not to talk to the patient, or ask him any questions, but let him remain silent, if, as is generally the case, he will. If, however, he talks in an excited way, a word or two may be addressed to him to calm him; and this condition lasts but a very few minutes.

I may remark here, that, except an oath once or twice, from patients who were probably in the habit of giving utterance to them, I have never heard anything said, under the effects of ether, which could not with propriety be repeated.

(*To be continued*)

NEW INVENTION

THE "CARDIFF" REMOTE CONTROL EXPIRATORY VALVE

By E. K. HILLARD

Department of Anæsthetics

Welsh National School of Medicine, Cardiff

THE valve illustrated (figs. 1 and 2) is a revised version of one described some three years ago (Mushin and Ezard, 1950). Constant clinical use has confirmed the need for and value of a valve of this type. In the present instrument the "shut off" mechanism, actuated by the remote control, is quite separate from the very lightly

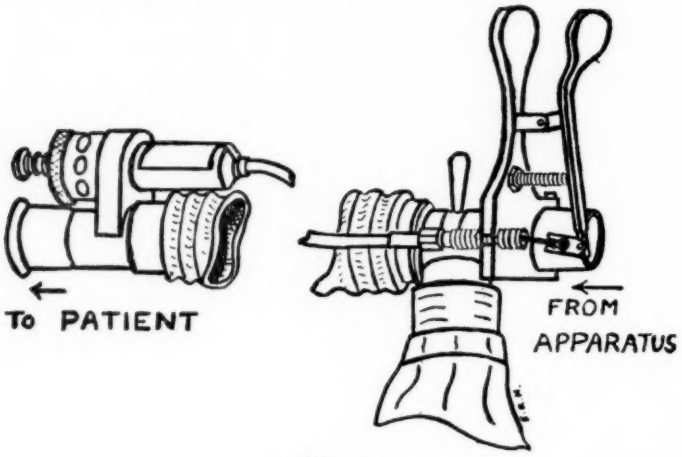

FIG. 1

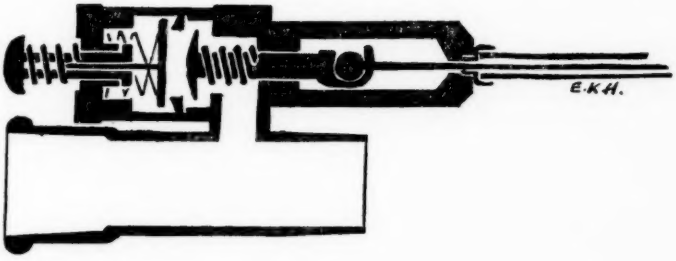

FIG. 2
Valve in section

sprung expiratory valve disc which operates during spontaneous breathing. The present Bowden cable is a standard bicycle part which can be obtained at any store. The lightness of the expiratory valve spring can be gauged from the fact that the resistance to an outflow of 25 litres per minute is 1.6 cm. water. The complete assembly can be obtained from Medical and Industrial Equipment Ltd., 10/12 New Cavendish Street, London, W.1.

REFERENCE

Mushin, W. W., and Ezard, D. (1950). *Brit. J. Anæsth.*, **22**, 186.

CORRESPONDENCE

THE F.F.A.R.C.S.

Sir,

In future it appears to have been decided that the F.F.A.R.C.S. will be awarded as follows:

(*a*) By an examination.

(*b*) By election of anæsthetists who have gained the D.A. since its standard was raised and the examination separated into two parts.

(*c*) By election of a certain undefined number of those who took the D.A. under the old regulations.

In order to avoid anomalies among Group (*c*) might I suggest that they be sent a questionnaire similar to that circulated when merit awards were first distributed, i.e. asking for particulars of scholastic attainments, consultant appointments, contributions to medical literature, etc. In particular information should be sought as to whether the anæsthetist concerned has anyone junior to him on the staff of his hospital(s) who is likely to be elected to the F.F.A.R.C.S. under Group (*b*). The fear of such an anomaly is worrying a great many established anæsthetists who took their D.A. under the old regulations when it was the highest diploma available in their specialty. Such men would be placed in an invidious position were their trainees, who took this examination under more stringent conditions, awarded F.F.A.R.C.S. and at the same time the senior men had nothing better to show than the D.A.

I am sure that no one envies the relevant sub-committee their task of choosing who shall be elected from Group (*c*), but there is little doubt that a questionnaire of this kind

would be of the greatest value in assisting them to make their choice.

A. H. GALLEY
(*King's College Hospital*)

Sir,

I would be glad of the opportunity of replying to Dr. Galley's suggestion regarding the award of the Fellowship of the Faculty without examination.

I can assure Dr. Galley that the Board of the Faculty have given most careful consideration to the point he raises, together with many other points which he has not mentioned.

I hope that at this juncture there will not arise correspondence in the Journals on this matter, since it is not possible for the over-all picture to be seen until towards the end of about a two-year period.

Yours faithfully,

BERNARD JOHNSON
(*Dean of the Faculty of Anæsthetists*)

REVIEWS

The Principles of Thoracic Anæsthesia Past and Present. By William W. Mushin and L. Rendell-Baker. Published by Blackwell. Pp. 172. 193 illustrations. Price 42*s*.

In the preface the authors state that " This is not a ' how-to-do-it ' book " and, of course, it is not. Here the reader will find no attempt to discuss the assessment and preparation of a patient for thoracic surgery, the niceties and details of anæsthetic technique during the operation, that all-important factor transfusion therapy, nor even any particulars of post-operative care. What will be found, however, is a fascinating historical review of the evolution of methods to control the situation when the pleura is opened, to ensure a perfect airway, and to limit the spread of pulmonary secretions.

Throughout, the old and the new are brought into suggestive proximity, and the intention is clearly to drive home the point that there is nothing new under the sun, a moral perhaps too often forgotten by our inventors. Large numbers of intriguing historical pictures to which certainly the majority of anæsthetists would not otherwise have access are collected together, and the authors are to be sincerely congratulated on the great deal of research which has gone into the compilation of this catalogue. At the end of the book there is an appendix in which are given thirty-three short biographies and miniature photographs of some of the outstanding pioneers in the development of modern thoracic surgery and anæsthesia.

It is an understatement to say that this is a completely

fascinating and all absorbing publication and one which no anæsthetist who has his craft close to his heart can afford to be without. Expensive perhaps, not to be wondered at in view of the number and quality of the illustrations, but still a very good two guineas' worth.

The Neurophysiological Basis of Mind. By J. C. Eccles. Published by Oxford University Press. Pp. 314. 86 illustrations. Price 25*s*.

It would be impertinent for an anæsthetist to review this book, perhaps the most significant since Sherrington's "Integration of the Nervous System". Physiologists have had their say in other places. It is the purpose of this note only to draw attention to its publication and to its outstanding importance to anæsthetists. Here will be found collected together the contemporary views and the evidence which has led physiologists to adopt them, on the ionic hypothesis, transmission at the motor end plate, in the autonomic ganglion, and in the central nervous synapse. Up to this point the treatise deals with essentials for anæsthetists and applied pharmacologists, but it goes further and postulates new physiological hypotheses for such abstruse concepts as those of will and memory.

In the last chapter the problem of the "ghost in the machine" is considered, "if by ghost we mean in the first place an 'agent' whose action has escaped detection even by the most delicate physical instruments". Here we enter the realm of philosophy, and it strikes the reader that Professor Eccles is a great enough man to know his limitations.

Theorie und Praxis der allgemeinen Anästhesie. By von Fritz Schon and L. Zurn. Carl Hanser Verlag. Munchen 1952. Pp. 228. 136 illustrations.

Continental Europe was long known for its advocacy of local and its disregard if not contempt for general anæsthesia. Since the war, efforts have been made to close the gap between itself and the English speaking countries in this respect. The anæsthetists who now populate the teaching hospitals outside the Iron Curtain have largely been trained in Britain and America, and the W. H. O. Anesthesiology Centre at Copenhagen has supplemented this work by training and supplying every year an additional number of well-trained men and women. A text-book such as this—one of the first in the German language since the war—must therefore be looked at with keen interest as evidence of how far this change of outlook in anæsthesia has progressed. Though entitled "The Theory and Practice of General Anæsthesia", the book is nearly all theory and very little practice. A disproportionately large amount of text is devoted to a compressed and somewhat tabulated account of respiratory physiology and the pharmacology of anæsthetic drugs. Then follows a rather expanded account of anæsthesia for dental and oral surgery. Only towards the end of the book, in a bare 40 pages, is Dr. Zurn given a chance to tackle the problems of general anæsthesia for major surgery. Within the limits of the space at his disposal Dr. Zurn has done a good job, covering his subject, though far from comprehensively and barely adequately. He touches briefly on most present day methods, including those of hypotension, relaxants and thoracic anæsthesia, including in the latter the use of bronchial intubation and blocking. British authors might note that credit for the diaphragm needle is correctly given to Olovson. Post-

operative care is discussed in a few well written paragraphs. The illustrations throughout the book are of high quality and take up a good deal of space. Several forms of anæsthetic apparatus are shown which will be new to British anæsthetists. Too many of the illustrations, however, do not deserve the size and prominence they get. The authors, and Dr. Zurn in particular, have made a good start, and if the book runs to a second edition the latter author should be allowed to expand his section on general anæsthesia to a much greater extent. The bibliography at the end of the book is one of the best features, being strikingly comprehensive and up to date. Classification of the references under subject headings would make them even more valuable than they are.

Press Guide to British Chemicals and their Manufacturers. Issued by the Association of British Chemical Manufacturers. Pp. 76.

We have received recently the " Press Guide to British Chemicals and their Manufactuers " issued by the Association of of British Chemical Manufacturers, 166 Piccadilly, London, W.1. The Table of Contents describes sufficiently the information to be found in this small book. The list of proprietary and trade names, with the nature of the substances to which the names are applied, and the names of the firm supplying should prove most helpful to those interested. The code number of the firms and their addresses can be found in another place in the book and also an index of products.

The accompanying letter suggests that journalists, broadcasters and lecturers will find the book useful but there are many others, including the heads and personnel

of university medical departments, and anæsthetists, to mention only a few, who will find here information they may be seeking. Those responsible for the issue of this book are anxious that it shall not be regarded as a directory or guide to sources of supply of chemicals, but as a guide to those seeking sources of information.

NEW FILM

On Wednesday, May 20th, Professor A. M. Boyd, F.R.C.S., Professor of Surgery at Manchester University, introduced the film, "Dextran—the new narrow fraction", at the Royal College of Surgeons, Lincoln's Inn Fields, London.

Over two hundred surgeons and anæsthetists saw the film, sponsored by Benger Laboratories Limited, which describes the progressive selection of the clinically optimal range of dextran molecules contained in "Dextraven"—the most useful substance yet discovered for maintenance of blood volume.

The "narrow" or optimal fraction of dextran results in a higher blood concentration of the colloid than has previously been possible and, in consequence, raises blood volume more rapidly and maintains it for a longer period.

A section of the film was devoted to the manufacturing process at Holmes Chapel, Cheshire. The audience saw the development of "Dextraven" from sugar, the raw material, through the fermentation process, which is carried out with the aid of cultures of Leuconostoc mesenteroids, hydrolysis and fractionation and finally the many biological and chemical tests which are carried out before this solution is released for use. They saw the dextran fractionated from a rubbery consistency to a clear solution having a viscosity similar to blood.

The surgical part of the film shows the clinical use of "Dextraven" at an operation on a patient suffering from biliary fistula carried out by Professor Boyd at the Royal Infirmary, Manchester.

It is claimed, for this new form of dextran, that it obviates the drawbacks of all other colloidal solutions previously available for use in place of blood or plasma for blood volume restoration. An important feature is its stability under any climatic conditions, which renders it of particular value in those overseas territories where highly organized blood transfusion services, as we know them in this country, do not exist.